Emissions of CO_2 and N_2O from volcanic soil under different crop management using closed non-fixed chambers

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Abstract
Agriculture soils may be a potential source of greenhouse gases, however it is not directly estimated yet in countries like Chile, which has special soil and climate conditions for a competitive agricultural activity and particular nutrient cycling patterns and processes in volcanic soils. The present work shows the first data of CO_2 and N_2O fluxes estimated from direct gas samples of passive chambers on volcanic soils in a crop system of Southern Chile. Gas samples were obtained from a oat-wheat rotation in a volcanic soil surface in Chile (36º S, 72º W) under two treatments of N fertilization (150 kg N/ha NH_4^+-and NO_3^--N, respectively) and two lime dose treatments (0,5 and 1 Ton lime/ha, respectively), from closed non-fixed chambers and fluxes of CO_2 and N_2O were estimated from a gas chromatograph concentration in function of time during gas accumulation in the chambers headspace in a period of 1 year. Soil variables, including temperature, water content and mineral N content were registered in order to check correlations with gas fluxes. Results show low emissions of GHG from volcanic soils of Chile and no important influences of some agriculture management and environmental variables.

Key Words
Greenhouse gases, agriculture, nitrogen, global change, air pollution.

Introduction
Agriculture is either a potential source or sink of Greenhouse Gases (GHG), mainly carbon dioxide (CO_2) and nitrous oxide (N_2O), which may contribute to the temperature increase of the atmosphere and climate change. The patterns of GHG emissions from Chilean soils and the related processes are of great interest for the different agricultura; scenarios in order to place Chile in the global agreements of mitigation policies. Pristine ecosystems of southern Chile still reflect efficient nutrient cycling, only comparable to pre-industrial ages (Huygens *et al.* 2008), thus, the biogeochemical patterns of volcanic soils in terrestrial ecosystems of southern Chile may promote nutrient retention and limit GHG emissions. However, ecosystem disturbances such as agricultural activities, disrupt the retention patterns in soil and favor nutrient losses, which may occur as GHG (Van Cleemput and Boeckx 2005). Agricultural activities are increasing at Southern Chile and will certainly change the environmental patterns and processes due to an intensive and inappropriate soil uses that should increase GHG emissions. Research on gas fluxes directly from the soil surface is seriously suggested in order to improve knowledge on GHG mitigation and future propositions of sustainable agriculture systems. A Chilean GHG inventory for agriculture activities has been made with empirical information from the International Panel for Climate Change (IPCC) (Novoa *et al.* 2000; Geng 2003; DICTUC 2004) and estimate a flux of 10.5 Tg eq.-CO_2/y, being the methane (CH_4) and N_2O, the main gases from this fountain, while CO_2 is generated mainly from plant respiration processes and is compensated during cycle of year. Such inventory is a proposed method related to the first uncertainty level (Tier 1) and allowed to have the baseline preliminary data. However, it is urgently necessary to quantify GHG emissions at different agroecosystems due to the variability of geographic location, climate, productive levels and management involved on, which will decrease the level of uncertainty (Tier 2) (IPCC 2007). Chile is one of the countries that have the conditions to be a leader in agricultural products with an environmental seal of low GHG emissions, because of its open economy, low country-risk and the international commercial agreements that make easier the transactions. A first methodological approach regarded to passive chambers to estimate GHG fluxes from soils (Livingston and Hutchinson, 1995; Hutchinson and Livingston, 2002), has been widely used in agriculture soils and contributed to the recent knowledge of *in situ* GHG emissions (Livingston *et al.*, 2006), and may be easily complemented with gas chromatography (Van Cleemput and Boeckx 2002). The GHG sampling *in situ* may be done from several agricultural systems under different soil and climate conditions including a non-equilibrium pattern like soil erosion events which have a major impact to atmospheric CO_2 (Follett *et al.* 2001). Soil respiration from crop systems represents 10 to 15 fold

greater CO_2 emissions than from fossil fuels (Raich and Schlesinger 1992). Emissions of GHG has been estimated *in situ* from several crop systems using similar methodology (Beauchamp 1997), as well as from N fertilized pastures (Groffman *et al.* 1993; Abbasi and Adams 2000), and related to environmental variables like soil temperature and water content (Choudhary *et al.* 2002; Ponce-Mendoza *et al.* 2006). The biological processes of nutrient cycling could be correlated to GHG emissions of soil through the chambers quantification (Smith *et al.* 2003; Roser *et al.* 2006). The present work presents the first values of GHG fluxes from crop soils in Chile using passive chambers and gas chromatography analyses.

Methods

Gas sampling was done in a long-term (12 years) field experiment of crop rotation (oat-wheat) in Southern Chile (36º S, 72ºW), on a volcanic (Typic Fulvudand) soil. Complete randomized blocks (n = 3) were set to assess the effect of N amendments and lime: nitrate-N fertilization; (T1); ammonium-N fertilization (T2); ammonium-N + 0.5 Ton lime/ha (T3); and ammonium-N + 1 Ton lime/ha (T4). The rate of fertilizer was 150 kg N/ha for every treatment. Gas sampling was done from March of 2008 to December January of 2009, every month and after important events of precipitations and crop fertilization. Passive closed non-fixed chambers (4 L) were set in soil surface and gas samples were collected each 15 minutes starting at time 0 from the chamber headspace during 45 minutes of gas concentration (Hutchinson and Livingston 2002; IAEA 1992). The concentrations of gases (µg/L) were estimated with a Perkin Elmer Clarus 600 Gas Chromatograph with a Porapak Q column and a Flame Ionized Detector plus methanizer for CO_2 and an Electronic Capture Detector for N_2O (Van Cleemput and Boeckx 2002). Fluxes of GHG were estimated for each sampling date with the linear relation of gas concentration in function of time and reported as Mg CO_2/ha/y and kg N_2O/ha/y. At each gas sampling date, different soil variables were registered in order to find correlation to GHG fluxes. Soil and air temperature (ºC) was registered with a digital thermometer, gravimetric soil moisture was estimated with a TDR di-electric detector and reported as percent of Water-Filled Pore Space (WFPS%) (Linn and Doran, 1991) and mg NH_4^+- and NO_3^--N kg soil were reported from estimations in FIA Star Foss mineral N analyzer. One-way ANOVA and Honest Tukey analyses of data were used to detect effects ($p<0.05$) of field treatments on GHG emissions and linear correlations to soil variables.

Results

Fluxes of CO_2 ranged from about 20 to 50 Mg/ha/y, mainly before the beginning of winter and during spring, being at much lower values in the other months (Figure 1). No clear differences were reported for CO_2 among different crop management and the seasonal variation seems to be the main factor of influence to CO_2 fluxes in volcanic soils of Chile. Fluxes of higher values of CO_2 fluxes corresponded to soil temperature about 13 °C and 80% WFPS (not shown), which must be the best condition of soil respiration at this agriculture zone. Fertilization and lime amendment to soil occurred during October, coinciding with favorable conditions of soil temperature and moisture. This fact masks crop management effects on gas fluxes. Fluxes of N_2O reported very negligible values never higher than 5 kg N_2O/h/y during the period of study and the environmental variables had no influence in these fluxes (data not shown)

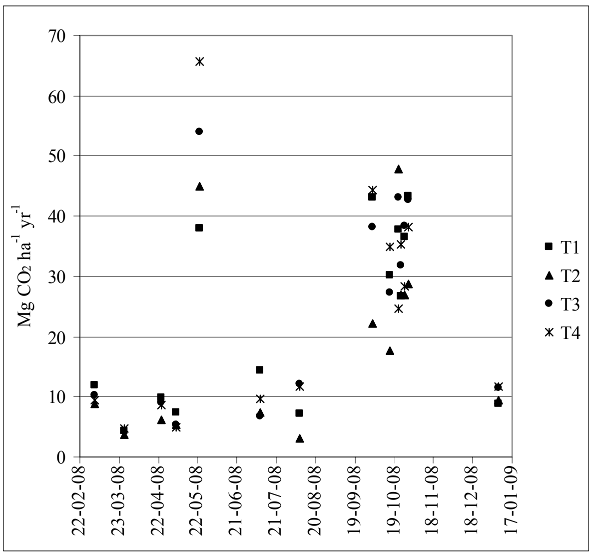

Figure 1. Fluxes of CO_2 (Mg/ha/y) from passive chambers at different crop soil management of N fertilization and lime amendments in a volcanic soil of Southern Chile during the study period.

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Results of GHG fluxes in Chilean volcanic soils with crop managements are initially indicating a conservative pattern that seems to have less influence of management or environmental variables. Compared to previous research (Choudhary 2002; Ponce-Mendoza 2006), the fluxes of gases in volcanic soils of Chile may support some agriculture activities without major impact.

Conclusion

The fluxes of N_2O were clearly negligible for every crop management (field treatments) and seem to have no influence of N amendments and lime. However, CO_2 fluxes responded to a season pattern being affected by soil temperature and moisture during the year, while a less clear effect of crop management also occurred with CO_2 emissions for this soil. Mineral N variation is apparently not related to GHG fluxes. The present data show initially that a volcanic soil of Southern Chile has a low potential of GHG emission under agricultural activities.

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