# Development of an Automatic Prototype to Measure Soil GHG Emissions within the Project LIFE AGRESTIC

Iride Volpi[1,2], Simona Bosco[1], Alberto Mantino[1], Benedetta Volta[3], Matteo Ruggeri[3], Pierluigi Meriggi[3], Giorgio Ragaglini[1]

[1]Institute of Life Sciences, Scuola Superiore Sant'Anna, Pisa, Italy. i.volpi@santannapisa.it, a.mantino@santannapisa.it, g.ragaglini@santannapisa.it (corresponding)

[2]AEDIT srl, Pisa, Italy.

[3]Hortasrl, Piacenza, Italy. b.volta@horta-srl.com, m.ruggeri@horta-srl.com, p.meriggi@horta-srl.com

## Introduction

Research should individuate and provide support to the spreading of strategies for greenhouse gas emissions (GHGs) reduction in the agricultural sector. In particular, efforts should focus on soil nitrous oxide ($N_2O$) emissions from non-flooded arable crops, as they are the major part of the global anthropogenic $N_2O$ emissions (Ciais et al., 2013). Mitigation of $N_2O$ emissions from soil could be achieved mainly by the optimization of N inputs to soil, as emissions mainly occur when there is a N surplus in soil, or when there is a bad synchronization between the N supply and the crop's demand (Snyder et al., 2014). Options to support farmers in optimizing N inputs, while achieving satisfactory yield, include model-based Decision Support Systems (DSS) and the design of efficient and low input cropping systems. Indeed, the introduction of legumes in the crop rotation may lower the N fertilizer requirements for the following crops and the use of agri-chemicals, allowing the reduction of fossil energy as well (Jensen et al., 2012). On the other hand, legumes may also be a source of $N_2O$ emissions due both to $N_2$-fixation and to the incorporation in the soil of N rich residues (Volpi et al., 2018). The most suitable and accessible way to measure GHG emissions from soil and to compare various treatments is the chamber technique (Livingston and Hutchinson, 1995). To date, most of the field experiments were carried out using static chambers and manual sampling, which introduce biases especially in the estimation of seasonal emissions due to the low frequency of measurement (Barton et al., 2015). Thus, the development of GHG measurement systems, based on automatic chambers and accurate analysers, can improve the quality of soil flux data and the estimation of seasonal GHG emission. Within the project AGRESTIC (Reduction of Agricultural GReenhouse gases EmiSsions Through Innovative Cropping systems - LIFE17 CCM/IT/000062 - https://www.agrestic.eu/en/) coordinated by Horta srl, a prototype for continuous measurement of soil GHG was developed to measure soil $N_2O$ and $CO_2$ emissions. This is aimed at assessing the potential GHG mitigation of Efficient Cropping Systems (ECS) based on the inclusion of legumes in crop rotations, both as pulses or intercropping species, and on the use of DSS, compared to a Conventional Cropping Systems (CCS), representing the business as usual of the farmers in the sites.

## Materials and methods

The field experiments are carried out at two sites: Ravenna (Cà Bosco farm) and Foggia (Caione farm), both characterized by a silty-clay-loam soil with an organic matter content equal to 1.4% and 2%, respectively. Crop rotations of the two cropping systems tested at each site are reported in Table 1. The design of the prototype included both an instrumental part for measurements (GHG station) and the development of an IT infrastructure to manage the data collected and to control the correct functioning of the instrumentation by remote. The project of the overall prototype was carried out by SSSA in collaboration with West Systems srl and AEDIT srl. The prototype should allow continuous soil flux measurement from winter 2019 to autumn 2022.

**Table 1**. Crops included in the Conventional Cropping Systems (CCS) and in the Efficient Cropping Systems (ECS) in the two sites.

| Ravenna | | Foggia | |
|---|---|---|---|
| CCS | ECS | CCS | ECS |
| Maize[1] | Pea[2] | Durum wheat[3] | Durum wheat[3] + alfa alfa[4] |
| Durum wheat[3] | Durum wheat[3] + alfa alfa[4] | Barley[6] | Sunflower[7] |
| Processing tomato[5] | Processing tomato[5] | Durum wheat[3] | Barley[6] + alfa alfa[4] |
| Durum wheat[3] | Durum wheat[3] + alfa alfa[4] | Sunflower[7] | Lentil[8] |

[1] *Zea Mais* L.; [2] *Pisum sativum* L.; [3] *Triticum turgidum* L.; [4] *Medicago sativa* L.; [5] *Lycopersicon esculentum* L.; [6] *Hordeum vulgare* L.; [7] *Helianthus annuus* L.; [8] *Lens culinaris* Medikus.

## Results

The instrumentation component of the prototype is the GHG station (Figure 1) which is able to (i) measure soil fluxes, (ii) to save and (iii) to transmit data. Emissions of $CO_2$ and $N_2O$ from soil are measured by 8 flow-through non-steady-state automatic chambers (four per cropping system). Other measured variables are: air pressure and air temperature within the chamber, soil water content and temperature using probes beside each chamber. An air-conditioned shelter contains: the analysers for $N_2O$ (Teledyne GFC-7002TU) and $CO_2$ (LI-COR LI-850), a multiplexer and a local processing unit which operate the measurement cycles of the eight chambers. The measurement time for each chamber last for 10 minutes. The chambers are connected to the shelter through a double pipe (inlet and outlet) of about 15 m long. Each automatic chamber is in aluminium alloy and it has an internal radius of 15 cm. A PVC collar 10 cm height is inserted for about 6 cm in the soil and the chamber is closing and opening on top of the collar. The chamber is equipped with a gasket to avoid air leakage during the closing time, a pressure controller, an air-mixing tube which guaranteed the homogeneity of gases concentrations within the chamber and a dust filter. An anti-radiation cover is placed on top of the chamber to avoid heating within the chamber. The IT infrastructure is based on a SQL database and Python routines to collect the data from the two GHG stations. The system is implemented with a R-based algorithm to: (i) select the best interval to calculate fluxes over the entire chamber closing time, (ii) calculate fluxes with different models, (iii) select the best model and (iv) check the quality of fluxes and assign flags according to quality levels. Raw, elaborated data and plots of GHG emissions and climate data are organized in a web interface together with farmer operations schedule. The GHG stations were installed and data acquisition started on 28th Nov 2019 in Foggia and on 12th Dec 2019 in Ravenna.

**Figure 1**. From the left: automatic chamber on bare soil; views of the GHG monitoring station with the eight chambers in Ravenna (winter) and Foggia (summer); automatic chamber in maize.

## Conclusions

The prototype will measure soil GHG emissions with an automatic and standardized procedure, allowing to:(i) collect and analyse data with high temporal resolution; (ii) assess the GHG mitigation of the Efficient Cropping Systems designed within the project AGRESTIC; (iii) evaluate the effectiveness of process-based models to improve the prediction of GHG emissions.

## Literature

Ciais et al., 2013. Climate Change 2013: The Physical Science Basis; Snyder et al., 2014. Agriculture: Sustainable crop and animal production to help mitigate nitrous oxide emissions. Curr. Opin.Env.Sus., 46–54; Jensen et al., 2012. Legumes for mitigation of climate change and the provision of feedstock for biofuels and biorefineries. A review, Agron. Sustain. Dev., 32:329–364; Volpi et al., 2018. Minimum tillage mitigated soil $N_2O$ emissions and maximized crop yield in faba bean in a Mediterranean environment. Soil Tillage Res., 178:11–21; Barton et al., 2015. Sampling frequency affects estimates of annual nitrous oxide fluxes. Sci. Rep.5:15912.