PhD School on Agriculture, Environment and Bioenergy

(http://sites.unimi.it/dottorato_aab/)

(XL cycle, 2024-27)

Project draft

1. Field of interest: Agronomy (AGR/02 - Agronomia e coltivazioni erbacee)

2. Project title: Estimation of GHG emission in intensive cropping systems with monitoring and simulation models

3. Tutor: Prof Alessia Perego

Co-tutor: Prof Giorgio Ragaglini

4. Relevance of the topic and state of the art

In Mediterranean climatic conditions, N_2O an CO_2 emission, along with the reduction of soil organic matter, is regarded as a relevant environmental issue. In intensive cropping system coupled with livestock production, the combination of agronomic practices as tillage operation, manure application and crop residue retention/removal strongly impact emission. Among drivers, crop residue decomposition is recognized as a potential source of emissions along with the positive effect on soil organic carbon accumulation (Fiorini, et al., 2020; Abalos et al., 2022; Hua et al., 2023); however, existing research on the impact of residue incorporation method (through tillage) and manure application on N_2O and CO_2 emission did not provide concluding evidence about the effects of factors involved. Retention of crop residue in the autumn on the soil surface instead of removal or incorporation with ploughing may especially result in decreased N_2O emission in winter and spring (Wagner-Riddle et al., 2017), but more studies are required to test this mitigation opportunity in the Mediterranean climate. Regarding CO_2 emissions, a gap of knowledge consists in the unknown contribution of the root and aboveground biomass respiration to the total soil-crop respiration (Du et al., 2020; Zheng et al., 2021). The eddy-covariance system coupled with automatic chambers can be applied to measure the contribution of such sources of emission, also allowing the estimation of the CO_2 emitted during residue decomposition.

An existing experimental field (Northern Italy) allows a comprehensive study of N_2O and CO_2 emission as mainly driven by the tillage, manure application and residue retention/removal, allowing the estimation of the potential decomposition rate, C to N ratio of residue, mineral N availability (both ammonium and nitrate), and soil organic carbon evolution (measuring the total stock and the fractions of particulate organic matter POM and mineral-associated organic matter MAOM). In this frame, agronomic solutions will be compared for the management of crop residues aimed at reducing N_2O and CO_2 emission and increasing the soil organic carbon stock.
As a further step in the analysis, the measured variables will be effectively applied to calibrate simulation cropping system models to assess what-if management scenarios at larger temporal and spatial scales.

5. Layout of the project

5.1. Materials & Methods

The following activities will be carried out during the 3-year period:

- Definition of agronomic practices to be evaluated in a 3-year field experiment: crop rotation including autumn and spring-summer crops and crop residue management (removal, retain on soil surface with no-till practice, soil incorporation with ploughing).
- Monitoring of N_2O and C_2O emissions at hourly time step in the experimental site in Landriano, PV (Azienda Angelo Menozzi) in the Po plain. This activity will be carried out

using the existing measurement system equipped with automatic and remotely manageable devices for the measurement of gas emissions from the ground through accumulation chambers.

- Frequent collection of ancillary data to get a full understanding of C, N, and water processes at different soil depths (e.g., 15, 30, 45, 60 cm): soil water content, soil temperature, NO_3, NH_4, POM, MAOM, crop residue amount on soil surface, and bulk density. Fertilizer application, irrigation, and crop data about phenology, yield, leaf area index, dry matter partitioning at harvesting will be also recorded periodically.
- Simulation model calibration: results from the field experiment will support the modelling analysis, particularly the calibration of at least one process-based simulation model, being capable of a close representation of N and C cycling. Calibration will target the parameters related to N_2O and CO_2 emission, mineralization and immobilization of organic C and N.
- Modelling analysis of N_2O and CO_2 emission and soil organic carbon evolution in response of crop residue management at the sub-continental scale for Mediterranean climate: the model will be then upscaled to simulate the tested agronomic practices at regional scale using available database of soil properties (regional soil map) and long-term weather data.

5.2. Schedule and major steps (3 years)

The research will be articulated in the following activities and tasks.

Activity	Task	Year 1	Year 2	Year 3
Experiment set-up	Definition of crop rotation and agronomic management to test	X		
Experimental data collection	Gas emissions and soil data. Data will be collected in a database ready to be effectively used in the modelling analysis.	X	X	X
Calibration of cropping systems simulation models	Parameterization of the simulation model	X	X	X
	Model validation		X	X
Modelling analysis at sub-continental scale	Collection of existing data of soil properties and long-term weather data		X	X
	Definition of agronomic management practices		X	X
	Interpretation and discussion of simulated emissions and soc evolution			X
Thesis and article writing			X	X

6. Available funds

PROENV (ERANET, European Union), 99,000 euro (principal investigator Prof Alessia Perego, Marco Acutis).

7. Co-Financing (to support grants): No

8. Literature

Abalos, D., et al., 2022. A review and meta-analysis of mitigation measures for nitrous oxide emissions from crop residues. Science of the Total Environment: 154388. DOI:10.1016/j.scitotenv.2022.154388

Du, K., et al., 2020. Differential influence of no-tillage and precipitation pulses on soil heterotrophic and autotrophic respiration of summer maize in the North China Plain. Agronomy, 10(12), 2004. DOI: 10.3390/agronomy10122004

Fiorini, A., et al., 2020. Combining no-till with rye (Secale cereale L.) cover crop mitigates nitrous oxide emissions without decreasing yield. Soil and Tillage Research 196: 104442. DOI:10.1016/j.still.2019.104442

Hua, K., et al., 2023. Long-term organic fertilisers application increase plant autotrophic, soil heterotrophic respiration and net ecosystem carbon budget in a hillslope agroecosystem. Plant, Soil & Environment, 69. DOI:10.17221/245/2023-PSE

Wagner-Riddle, C., et al., 2017. Globally important nitrous oxide emissions from croplands induced by freeze–thaw cycles." Nature Geoscience 10.4: 279-283. DOI:10.1038/ngeo2907

Zheng, P., et al., 2021. Effects of drought and rainfall events on soil autotrophic respiration and heterotrophic respiration. Agriculture, ecosystems & environment, 308, 107267. DOI: 10.1016/j.agee.2020.107267