FACCEJPI

SOILS MANAGEMENT UNDER CLIMATE CHANGE MITIGATION

AGRICULTURAL PRACTICES HAVE A KEY ROLE IN THE INTERNATIONAL CLIMATE CHANGE AGENDA

This article is written by Dr Chaden Diyab from FACCE-JPI with contributions from Dr Sylvie Recous, Dr Gianni Bellocchi, INRA, France (CN-MIP), Dr Val Snow, AgResearch Limited, New Zealand (Models4Pastures), Dr Jeff Novak, United States Department of Agriculture-Agriculture Research Service, USA (Designchar4food), Dr Rebecca McCulley University of Kentucky, USA (EndoGas), Dr Steven Sleutel, Ghent University, Belgium (GreenRice)

Soil is a critical component of the land. It fulfills numerous ecologically important functions and offers a variety of ecosystem services that are essential terrestrial ecosystems and to maintain biological diversity and productivity. Improvement of soil quality by adoption of recommended management practices will help to sequester carbon, reduce anthropogenic emissions, improve the environment, and enhance and sustain agronomic productivity.

Beyond carbon dioxide (CO_2) and methane (CH_4), agricultural cropping and animal production systems are notable sources of atmospheric nitrous oxide (N2O). It is estimated that agricultural systems produce about one quarter of global N_2O [(1)] emissions. Methods for mitigating these emissions are discussed here which, if adopted globally, could decrease annual N_2O emissions from cropped soils by about 20% [(2)]. The implementation of climate smart agricultural practices, the development of technical applications as well as appropriate policies and practices could improve the quality of soil within the context of climate mitigation activities.

Dr Chaden Diyab, responsible for the valorisation of FACCE-JPI research projects, interviewed project coordinators of the FACCE-JPI Multi-partner Call on Agricultural Greenhouse Gas Research. In this paper, a summary of some projects is presented to illustrate potential and emerging applications of project results to face the challenges of climate change adaptation and mitigation. These include various agricultural practices and innovations such as Greenhouse Gas (GHG) calculators, new technologies and innovative resource management.

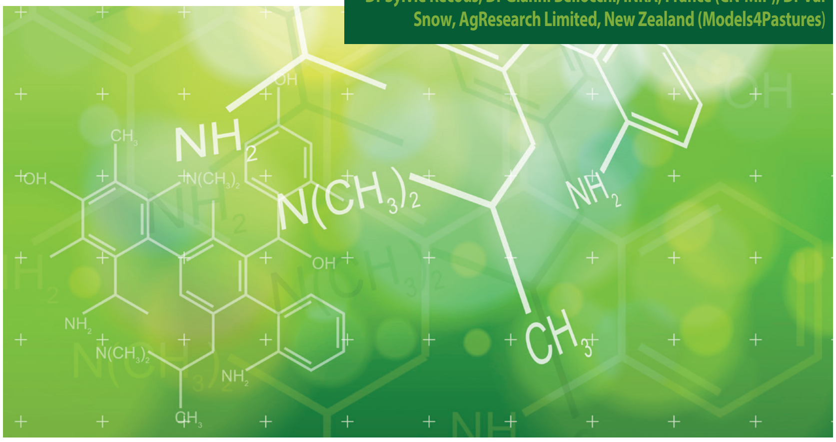
What is the FACCE-JPI and the Multi-partner Call?

FACCE-JPI is the Joint Programming Initiative on "Agriculture, Food security and Climate Change". Today it brings together 24 European and associated countries as well as New Zealand to coordinate their research capacities to address the vital challenge of ensuring sufficient production of food, as well as feed, fibers and bio-fuels, in the context of demographic growth and a changing climate.

The Multi-partner Call on Agricultural Greenhouse Gas Research, initiated by FACCE-JPI, is supported by 11 FACCE-JPI members as well as the National Institute of Food and Agriculture of the U.S. Federal government, New Zealand's Ministry for Primary Industries and Agriculture and the Canadian Department of Agriculture and Agri-Food. The call was designed to bring together excellent research consortia to enhance international collaboration in the face of the global challenge of climate change adaptation and mitigation.

GHG CALCULATORS FOR OPTIMAL PREDICTION OF GREENHOUSE EMISSIONS AND EVALUATION MITIGATION PRACTICES

Dr Sylvie Recous, Dr Gianni Bellocchi, INRA, France (CN-MIP), Dr Val Snow, AgResearch Limited, New Zealand (Models4Pastures)



Nitrous oxide, carbon dioxide and methane are the main biogenic greenhouse gases (GHG) contributing to a net increase of GHG within agro-ecosystems. Evaluating the impact of agriculture on climate warming therefore requires the capacity to predict the net exchanges of these gases using a systemic modelling approach that is responsive to environmental conditions and agricultural management.

This can be achieved using GHG calculators, which provide an accessible approach to estimate GHG impacts from agricultural sources because they are inexpensive, rapid, and are a relatively lower knowledge-intensive option than other GHG quantification alternatives, such as in-situ measurement campaigns or process-based models. However, these GHG quantification methods can only be applied retrospectively (i.e. once production and management are known) so a role exists for the combination of measurements and the usage of process-based models to support the development of calculators.

Two of the funded projects (CN-MIP and Models4Pastures) [(3)] have contributed to this objective through their collaboration to test the robustness of process-based models and their ability to predict GHG emission reduction (e.g. carbon sequestration) across a wide range of climatic conditions and agricultural practices. Project results have indicated the requirement for an initial calibration process. The research confirmed that model calibration is difficult as there is a lot of variability in the measured data. In addition, for application to crop rotations a calibration of the timing of the physiological states (regarding flowering, senescence, etc.) is required to substantially improve the model's performance.

On the other hand, for grassland systems, there was little improvement when data were supplied to calibrate the models. This is likely due to differences in the underlying principles and the variability in the processes of models (crop models are often fundamentally based on physiological states, whereas pasture models often are typically not). Moreover, grasslands are mostly managed to stay within a narrow range of physiological states. It is also difficult to know the timing of the physiological states for a chosen location so in this respect it is easier to use models for predicting grassland systems than cropping systems. In addition, both the measurement and prediction of yield and N_2O emissions in permanent grassland systems is complex and only 20% of individual models were within a plausible range (defined as two standards deviations of measured yield and one standard deviation of measured N_2O emissions).

In both cropping and grassland systems, models are most robustly used when they are within an ensemble approach. The ensemble of model results is consistently a better predictor of production and GHG outputs, where no single model is the best under all circumstances across climates and management systems. From a policy perspective, it is critically important to identify the extent to which management interventions are likely to affect productivity and GHG fluxes prior to promoting policies in favor of alternative farming practices. From this perspective, process-based, biogeochemical models can contribute to the improvement of the national inventories of GHGs in a wide range of pedo-climatic and management conditions. In addition, the effect of management on carbon and nitrogen fluxes in agricultural systems is always uncertain to some degree and such uncertainties are reflected in the outputs of biogeochemical models that are used to simulate responses to management. Notably, this modelling approach is supported by the Global Research Alliance for Agricultural Greenhouse Gases and the 4 per 1000 initiative, indicating that biogeochemical models hold potential for application at a global scale.

Key findings

- **An ensemble of models has been consistently shown to provide better estimates of yield and GHG emissions, than even the best model, and can therefore support sound mitigation practices.**
- **Using an ensemble of models should be seen as a minimum standard for robust analysis.**
- **An ensemble of models will also convey information about the uncertainties associated with the proposed mitigation.**
- **Process-based models are generally not suitable for inexperienced users (although constrained user interfaces can assist here) but they are highly suitable to aid the development of simpler GHG calculators.**

EMERGINH TECHNOLOGIES CONTRIBUTING TO CLIMATE CHANGE MITIGATION

Dr Jeff Novak, United States Department of Agriculture-Agriculture Research Service, USA (Desigchar4food), Dr Rebecca McCulley University of Kentucky, USA (EndoGas)

To cope with the challenges of climate change and sequestration of greenhouse gases, effective and practical techniques are required for their increased storage within the soil.

One possible technique is through biochar applications. Biochar is a byproduct from the biofuel production industry. Scientific experimentation has shown that biochar has the ability to absorb nitrogen, thus reducing GHG emissions. The DesignChar4food project showed that through designer biochar application, both soil carbon sequestration and nitrogen fertility can be enhanced while reducing soil GHG emissions.

Scientists in this project also demonstrated that biochar has the ability to decrease nitrous oxide emissions. A meta-analysis of the existing literature indicated that a drop in nitrous oxide can be accomplished by applying biochar that was pyrolyzed at temperatures above 500 °C. At these high temperatures, the biochar structures are resistant to microbial oxidation, so microbial activity is lower and subsequently less nitrogen is reduced to nitrous oxide. Collaborators on this project also demonstrated that when biochar is mixed with soil and a nitrification inhibitor is added, nitrous oxide formation is decreased. In this last case, chemical inhibitors could track specific microbial mechanistic pathways for nitrogen reduction.

Grass-fungal endophyte symbiosis is another approach that is being explored for reducing GHG emissions and enhancing carbon sequestration within the soil of pasture-based animal agricultural production systems. In the case of project 'EndoGas,' researchers are evaluating three different grass-endophyte associations (meadow fescue - Epichloë uncinata, red fescue - Epichloë festucae, tall fescue - Epichloë coenophiala) grown in a variety of locations, including the Faroe Islands, Finland, Spain, and the United States. Previous work [4,5] suggested that aboveground fungal endophyte infection stimulated soil carbon sequestration in tall fescue stands in the United States. However, this study failed to substantiate these findings, as no significant differences in soil organic carbon stocks were found between endophyte-infected and endophyte-free stands or individuals of any of the three grass-endophyte associations evaluated at all locations. Endophyte infection caused meadow fescue stands in Finland to switch from being a source of methane (286 g C ha-1 yr-1) to a methane sink (-476 g C ha-1 yr-1) and also caused reductions (by 6-18%) in CO_2 and N_2O emissions. However, significant temporal and spatial variability in greenhouse gas fluxes caused these patterns to not be statistically significant. Endophyte effects on tall fescue greenhouse gas fluxes in the United States were more subtle and also not significant. It is possible that previously observed endophyte effects on pasture soil carbon and greenhouse gas fluxes were driven by indirect endophyte-associated effects on grazing animals and resulting management practices. Further work on the soil microbiome is required to investigate its possible applications in reducing GHG emissions and contributing to resilience.

Key findings

• Using biochar as a soil additive, there is a high potential to increase soil carbon sequestration, improve nitrogen availability and reduce nitrous oxide emissions. These are important components of strategies for sustainable land management.

• The soil microbiome is receiving increasing attention as a potentially under-utilized biotechnological tool for improving cropping system resilience and combatting climate change.

• Future studies incorporating animal production are warranted to further evaluate the potential of grass-endophyte as a tool for enhancing grazing system mitigation and resilience.

BETTER MANAGEMENT OF NATURAL RESOURCES

Dr Steven Sleutel, Ghent University, Belgium (GreenRice)

Smart agricultural practices for effective resource management could who assist also in indirectly reducing GHG emissions. Compelled by the diminishing availability of freshwater in major irrigated rice growing regions, the GreenRice consortium evaluated the impact of reduced water use on the global warming potential of rice-based cropping systems. However, it is very difficult to experimentally investigate the net greenhouse gas balance for even the most common possible combinations of management practices and soil types (amongst other key factors). Therefore, the project aims to share knowledge on key biogeochemical paddy-soil processes that increase in importance with non-continuous flooding management techniques and translate advances into a biogeochemical model. Up until now, rice paddy field experiments with intense follow-up of GHG emissions and biochemical drivers in soil have been completed in northern Italy and Bangladesh. The team from GreenRice have identified source-processes of soil borne N_2O and the relevancy of the role of CH_4-oxidation in irrigation management. The team also evaluated impacts of a supply reduction of iron and manganese and soil nitrogen. These insights will be synthesized in the mechanistic biogeochemical model known as DNDC to better predict soil GHG production.

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