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Global Research Alliance on Agricultural Greenhouse Gases

Croplands Research Group

Action Plan

Goal

At the turn of the millennium, ~34% of the Earth's ice-free land surface was occupied by crops and pasture (Ramankutty et al., 2008). Our land currently feeds >6 billion people, but by mid-century will be expected to feed ~9 billion people – either by expanding agricultural land to currently uncultivated areas, increasing production from current agricultural land, increasing harvest of aquatic life, or a combination. This increasing human pressure on the Earth is of great concern and a key reason why agricultural and natural resource sciences must be fully engaged to develop solutions for a sustainable future.

Globally, agriculture is estimated to produce 6.1 Pg CO_2e/year (World Resources Institute, 2005). Agricultural emissions of greenhouse gases (GHGs) could increase to 7.9-8.5 Pg CO_2e/year by 2050, as the agricultural sector seeks to meet an expected doubling of food demand. Agriculture has inherent GHG sources that are unavoidable consequences of production:

- methane (CH_4) emissions from animal manure, enteric fermentation in ruminants, and paddy-rice cultivation;
- nitrous oxide (N_2O) emissions from agricultural soils amended with fertilizer, legumes, and animal manures;
- carbon dioxide (CO_2) emissions from on-farm biochemical processes, energy expenditures, and embodied emissions in machinery, buildings, and chemical inputs.

These GHG emissions cannot be expected to be zeroed, but there are opportunities to reduce GHG intensity per unit of land and per unit of food product (Eckard et al., 2010) and to reduce existing net CO_2 emissions via increased sequestration of carbon in agricultural soils (Franzluebbers, 2010). There may also be opportunities to use bio-based agricultural products to substitute for more GHG-intensive fuels and materials produced from fossil fuels.

Member countries of the Alliance recognize opportunities to reduce GHG emissions and sequester carbon in soil by improving the efficiency and productivity of agricultural systems through robust ecologically-based management practices and technologies, as well as developing novel approaches. By capturing these opportunities, not only will agricultural GHG emissions be mitigated, but resiliency and adaptive capacity of agriculture to meet the growing demand for food in a sustainable manner amidst global environmental changes will be an expected outcome.

Relationship to Ministerial Statement and to other Research Groups

During formation of the Alliance in 2009, government ministers endorsed the following objectives:

- Improve knowledge sharing, access to, and application by farmers of the numerous GHG mitigation and carbon sequestration best management practices and technologies, many of which can also enhance productivity and resilience;
- Facilitate the exchange of information among scientists around the world;
- Help scientists around the world gain expertise in mitigation knowledge and technologies through new partnerships and exchange opportunities;
- Develop the science and technology needed to improve the measurement and estimation of GHG emissions and carbon sequestration in different agricultural systems;
- Promote consistent methodological approaches for the measurement and estimation of GHG emissions and carbon sequestration to improve research coherence and the monitoring of mitigation efforts;
- Enhance synergies between adaptation and mitigation efforts; and
- Build partnerships among farmers and farm organizations, the private sector, international and regional research institutions, foundations, and other relevant government and non-governmental organizations to facilitate and enhance the coordination of research activities and dissemination of best practices and technologies.

The Croplands Research Group aims to support all of these objectives through various research and technology transfer activities described in the following.

Component 1: Quantifying Net GHG Emissions in Cropland Management Systems

Croplands are sensitive to climate change and are a net contributor to GHG emissions. Croplands are also diverse in time, space, and variety of crops grown around the world. There is a need to quantify the role of the large diversity of cropland management systems to reduce GHG. Some of the primary management techniques that have worldwide relevance for soil carbon sequestration and GHG emissions are primary crop, crop rotation, cover cropping, fertilization, tillage, and residue removal. Results have been variable, but without a meta-analysis of the data, it is difficult to interpret the cause of variability (e.g. function of soil, climate, and agricultural conditions). There is a need to synthesize this information to propose a set of best management practices (BMPs) for particular soil types, ecoregions, etc.

Research needs

Research is needed to identify the components of a cropping system that have an impact on soil C sequestration, GHG emissions, and other environmental responses, both positive and negative. Under the diversity of private, university, and federal agricultural research networks around the world, there is a need to establish a searchable literature database, as well as to conduct a thorough review of the literature so that we might know better the gaps and the most fruitful strategies forward. The Alliance network allows us a unique opportunity to develop a global network of experimental sites and research expertise. Data

collected from the Croplands Research Group will be shared with the C and N Cross-Cutting Group to facilitate model development and verification. Finally, there is an urgent need to quantify indirect GHG emissions derived from agricultural activities.

Anticipated products

- Standardized / acceptable protocols and improved methods for determining soil C sequestration and GHG emissions;
- An international database of existing and new research on GHG fluxes and soil C sequestration rates as affected by particular agricultural management systems;
- A synthesis of currently available experimental results around the world;
- Guidelines / BMPs for minimizing GHG emissions and maximizing soil C sequestration under various climatic conditions, ecoregional delineations, and/or soil types; and
- Summary documents for use by international negotiating bodies concerned with GHG emissions, soil stewardship, and natural resource management.

Potential benefits

- Standardized datasets and data management protocols will enhance research opportunities by various nationally led research organizations;
- Greater international cooperation will be expected so that multi-national research efforts can be expanded with funding eventually supported for specific research goals derived from Alliance activities;
- Enhanced ecosystem services, such as climate regulation, C and N cycling, water infiltration and cycling, biodiversity enhancement, and scenic landscapes, will be an outcome that can benefit society in general.

Resources

This component is currently led by Guy Richard (France) and Charles Rice (USA). 21 members of the Cropland Research Group indicated an interest in participation in this component of our action plan at the March 2011 meeting in Grignon, France. The countries and scientists represented include:

- Argentina – Miguel Taboada (mtaboada@cnia.inta.gov.ar)
- Australia – Bill Slattery (bill.slattery@climatechange.gov.au)
- Canada – Denis Angers (denis.angers@agr.gc.ca)
- Chile – Jose Maria Peralta (jperalta@inia.cl)
- Denmark – Soren Peterssen (soren.o.petersen@agrsci.dk)
- Finland – Kristiina Regina (kristiina.regina@mtt.fi)
- France – Guy Richard (guy.richard@orleans.inra.fr), Sylvain Pellerin (Pellerin@bordeaux.inra.fr), Sylvie Recous (sylvie.recous@reims.inra.fr)
- Germany – Heinz Flessa (Heinz.flessa@vti.bund.de)
- Indonesia – Nyoman Widiarta (manwidiarta@yahoo.com)
- Ireland – John Spink (john.spink@teagasc.ie)
- Malaysia – Mohamad Zabawi Abdul Ghani (bawi@mardi.gov.my)
- Mexico – Juan de dios Benavides (Benavidez.juandedios@inifap.gob.mx)
- Norway – Lillian Oygarden (Lillian.oygarden@bioforsk.no)
- Peru – Beatriz Sales Davila (bsales@inia.gob.pe)
- Spain – Maria Luisa Ballesteros Jareno (mlballes@marm.es)
- Sweden – Åsa Kasimir Klemedtsson (asa.kasimir@gvc.gu.se), Thomas Kätterer (Thomas.katterer@slu.se)
- Thailand – Pornpun Sutthiyam, Yuthasart Anuluxtipun (yuttchai2004@yahoo.com)

- United Kingdom – Kathryn Morely (Kathryn.morley@defra.gsi.gov.uk)
- USA – Steven Shafer (steven.shafer@ars.usda.gov), Alan Franzluebbers (alan.franzluebbers@ars.usda.gov), Charles Rice (cwrice@ksu.edu)
- Uruguay – Jorge Sawchik (jsawchik@le.inia.org.uy)
- Vietnam – Nguyen van Viet (nvvietvaas@vnn.vn)

Component 2: Assessing GHG Emissions in Agricultural Peatlands and Wetlands

Agricultural production systems (i.e. croplands) are cultivated on mineral soils, peatlands, and wetlands. In some countries and regions, peatlands and wetlands constitute an important part of the available land resource. Globally, agriculture is the most common use for peatlands (Oleszuk et al., 2008). Previous research has focused on how to utilize peatlands for different purposes, including cultivation for agriculture, mainly because of their high fertility and inherent value for cultivation. However, GHG emissions from cropping systems cultivated on peatlands and wetlands can be several-fold greater than from cropping systems on mineral soils. This is sometimes due to the type of cropping and management systems, but also due to cultivation itself, with the inherent necessity for drainage of peatlands to be productive for agricultural crops. Drainage enhances decomposition of peat and leads to enhanced emission of CO_2 and N_2O, but reduced emission of CH_4 (Oleszuk et al., 2008). Current research is focused on mitigating GHG emissions from peatlands and wetlands.

Peatlands that have been continuously cultivated for many years will subside, oftentimes leading to questions by society about their suitability for cropping and the need for restoration to a more natural state to reduce further GHG emissions. Further, climate change in boreal regions is expected to lead to thawing of permafrost, which would further increase GHG emissions from peatlands. Peatlands are also used for other purposes than cropping, suggesting that our research is needed in a broader societal context.

Research needs

A global overview / synthesis of peatland resources and GHG emissions related to agricultural activities is needed. Although peatlands predominate in boreal regions of the world, other ecoregions have significant peatlands and wetlands as well. Therefore, soil C sequestration and GHG emission research is of interest to the global research community, especially since previous research has documented the importance of these unique soils for significant GHG emissions (Oleszuk et al., 2008; Maljanen et al., 2010). Peatland soils are sensitive to climate change, and at same time, are important for determining net GHG emissions. Country-specific research on peatlands could, therefore, be complemented with research from a global network to broaden the research experience and develop synergies among research scientists at different institutions and working under different environmental conditions. Results from such research will be a valuable input to Components 1 and 3 of this Cropland Research Group Action Plan.

Research will focus on the following:

- Quantification of GHG emissions from peatlands and wetlands in different geograpical regions, climate conditions, cropping systems, and management practices;

- Implementation of improved management strategies to reduce GHG from cropping on peatlands, e.g. cover cropping, residue management, fertilization, crop rotation, tillage system, and drainage regime;
- Restoration methods to preserve peatlands and reduce GHG emissions;
- Recommendations for improved cultivation methods and crop management strategies on newly cultivated peatland soil brought into production (e.g. as a result of thawing of permafrost or expanding cropland for food production); and
- Development of a global network of experimental sites to conduct synergistic research on soil C sequestration and GHG emissions.

Anticipated products

- Overview reports of ongoing research / status of peatlands related to GHG emissions (e.g. reports posted on Alliance website will give information about regional activities, research group members, and research summaries of existing and recommended practices in member countries);
- Publications / reports on recommended BMPs and their impacts on reducing GHG emissions, as result of this new joint research cooperation;
- Compilation of GHG emission datasets that will contribute to the efforts of Component 1 about GHG emissions from cropland management systems, as well as be available for use in proposed C and N modeling research in Component 3;
- Recommendations for improved technologies / BMPs to restore peatlands to a state of more naturally occurring ecosystem functioning; and
- Data available for the Alliance cross-cutting research team on inventories and measurement methods, through knowledge transfer, datasets, discussion notes for methods, overview of existing methods, and contributions at seminars or other discussions forums.

Potential benefits

Overview and synthesis products will be valuable in educating the science community, and society in general. Society can find a contact point and webpage giving regional information about status, ongoing research, and recommended practices. This can give background for policymakers seeking information about possible practices, recommendations, and actions from different regional areas. It also gives possibilities to establish contacts at different levels and to different groups in the Alliance. These activities can be part of the knowledge base when both national and international strategies and regulations are developed.

For science, there are additional benefits:

- Possibilities to contact other research groups for possible joint research;
- Harmonizing methods and guidelines for possible collaboration / utilization of experimental sites;
- Joint modeling investigations;
- Increased possibility to spread research information / results to a global scientific community; and
- Through a link to the cross cutting issues team on inventories and measurement methods, the scientific community will further benefit from the joint work.

It is expected that a strong international network bringing active research groups together will also increase the possibilities for securing multi-national research funding. Funding mechanisms have yet to be identified in this early stage of the Alliance.

Resources

This component is currently led by Lillian Oygarden (Norway). The Alliance has a regionalized network of researchers working with GHG emissions from peatlands and wetlands. The countries and scientists represented include:

- Canada – Denis Angers (denis.angers@agr.gc.ca)
- Finland – Kristiina Regina (kristiina.regina@mtt.fi)
- Malaysia – Mohamad Zabawi Abdul Ghani (bawi@mardi.gov.my)
- Norway – Lillian Oygarden (Lillian.oygarden@bioforsk.no)
- Sweden – Åsa Kasimir Klemedtsson (asa.kasimir@gvc.gu.se)

Component 3: Modeling C and N Emissions

The focus of this component is on simulation modeling of nitrous oxide (N_2O) emission and soil organic carbon (C) stocks and changes, because of the importance of these two processes on the global GHG budget of cropland soils.

Nitrous oxide emission is a result of two soil microbiological processes: nitrification and denitrification. These processes depend on many variables (N and organic C substrate availability, temperature, soil water content), which are controlled by climatic and soil factors, as well as agricultural management practices. Nitrous oxide emission is characterized by a high variability in space and time. Therefore, it can be difficult to measure without enormous investments in time, equipment, and labor resources. Difficulties are also present in interpreting and comparing data from different experiments. Existing models range from complex process-based models simulating the dynamic of water, solutes and microbial processes on a fine-scale (DNDC, DAYCENT, Ecosys, etc.) to simple, empirical tools based on statistical inference.

Soils are an important stock of C and changes in the soil C stock affect the net emission of CO_2 to the atmosphere. Long-term change in soil C stocks depends on the amount and nature of organic matter input and on numerous soil and climatic factors and agricultural management practices, which affect organic matter decomposition. Current understanding of how multiple interacting factors influence soil C dynamic has been embodied in a wide range of soil organic matter models (e.g. Century, RothC, AMG, etc.), which have a common theoretical basis, but which also differ according to numerous aspects (e.g. the number of organic component pools, time steps, etc.).

A major objective of the Alliance is to identify and develop agricultural practices that improve the global GHG budget of cropping systems. Both N_2O emissions and soil C dynamics are strongly influenced by agricultural management practices, although at different time scales. Responses of C and N dynamics depend on many circumstances. Simulation models are needed to decipher the relative effects of soil properties, climate, and agricultural management practices for a wide range of circumstances. Their use is however hampered by the lack of synthesis documents giving an overview of existing models and of their possible use.

Research needs

Few review articles have been published about N_2O emission modeling (Chen et al., 2008). This is less the case for soil C models, probably because research in this area has been active for a longer time. It remains difficult, however, to easily select the model that best suits a

specific objective in a specific set of conditions or circumstances. This is especially true for non-modeling groups. One of the key considerations in selecting an ideally suited model is the requirement for input data to obtain a useful output from the model. Secondly, availability of data at the national level will also be needed for national inventory purposes. Therefore, the domain of the model (i.e. field or farm level or national inventory level) needs to be clearly selected and input data collected accordingly.

A major objective of this component will be to provide synthesis products that will be helpful for scientists (modelers and experimentalists) and agricultural managers and policy makers to get an overview of existing models, their input requirements, their potential outputs, and the purposes for which they are relevant. Inter-comparison of models and benchmarking are not in the scope of the group. This will be done by the C and N cycling cross-cutting team.

Anticipated products

- List of publications using N_2O emission models;
- List of publications using soil organic C models;
- Review articles describing N_2O emission models;
- Review articles describing soil organic C models;
- Bibliometric analysis of the worldwide scientific literature on both topics and a map of the main research groups that are active on these topics;
- Evaluation of models of direct N_2O emissions with information on the following:
    - spatial scale (e.g. laboratory, field, landscape, regional, etc.);
    - time scale;
    - input data requirement;
    - main simulated processes;
    - context and range of situations tested;
    - purposes for which they are suitable (e.g. test of researcher hypothesis, decision support system for mitigation, regional inventories, etc.);
    - main related publications;
- Evaluation of models of soil C dynamic (with information similar to that described for modeling of N_2O emissions above);
- Short list of recommended models that have been widely used and tested in a wide range of situations for a particular set of conditions and purposes; and
- List of models that use a mass balance approach in considering the cycling of both C and N within the same model framework.

Potential benefits

- For model users, an easier and better selection of models to suit specific goals;
- Facilitated access to models for a range of purposes;
- For the scientific community, experimental data interpretation;
- Soil C change and N_2O emission prediction and inventory; and
- In conditions or regions without extensive field experimentation, widespread identification of agricultural management practices that minimize N_2O emission and sequester C in soils.

Resources

This component is currently led by Sylvain Pellerin (France). Participating countries identified thus far include:

- Australia – Bill Slattery (bill.slattery@climatechange.gov.au)

- France – Sylvain Pellerin (Pellerin@bordeaux.inra.fr), Sylvie Recous (sylvie.recous@reims.inra.fr), Guy Richard (guy.richard@orleans.inra.fr)
- Thailand – Yuthasart Anuluxtipun (yuttchai2004@yahoo.com)
- USA – Steven Shafer (steven.shafer@ars.usda.gov), Alan Franzluebbers (alan.franzluebbers@ars.usda.gov), Charles Rice (cwrice@ksu.edu)

Program Data Management

The need for high-quality, scientific data on soil C sequestration and GHG emissions is critical for the success of the Croplands Research Group. We expect to gather data and work closely with the cross-cutting teams on (1) C and N cycling and (2) inventories and measurement to assemble these data into an efficient and usable format for widespread dissemination to the scientific community. We expect to receive guidance from the two cross-cutting teams as to the details of data requirements so that they will be utilized and transferable across different purposes.

Published primary data and associated metadata will be assembled in a format similar in structure to the GRACEnet database project (www.ars.usda.gov/gracenet) being developed in the USA.

Synthesis and Integration of Research Findings

Overview documents stating the progress and results obtained from the Croplands Research Group will be a priority. Periodic development of such documents will be discussed at annual meetings of the Croplands Research Group and/or Alliance-wide meetings. Documents will be posted on the Alliance website at: www.globalresearchalliance.org.

The Croplands Research Group is expected to develop regional projects / workshops / symposia that will summarize soil C sequestration and GHG emissions from cropping systems within a particular regional context. Such regional meetings will help foster steps toward global integration of knowledge and data sharing.

Networking of scientists involved in the Alliance will be encouraged at annual meetings of the Croplands Research Group. Country reports will be expected on research findings and regional- and global-scale updates and syntheses will be discussed.

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