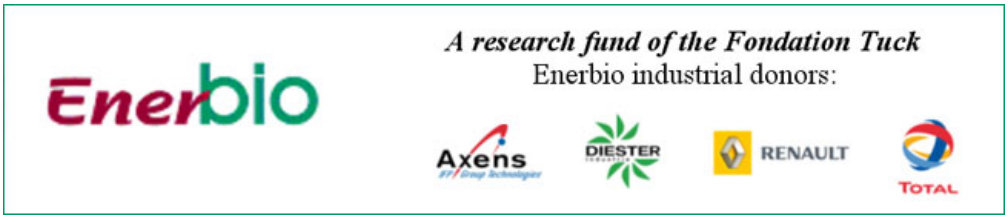
IMAGINE : IMproved Assessment of the Greenhouse gas balance of bioENergy pathways



PROJECT 2009

Title of the project	**IMproved Assessment of the Greenhouse gas balance of bioENergy pathways**
Acronym	IMAGINE
Coordinator	UMR INRA AgroParisTech, Environnement et grandes cultures, 78850 Thiverval-Grignon *Responsable scientifique : Benoît Gabrielle*
Partners	LSCE (Laboratoire des Sciences du Climat et de l'Environnement), L'Orme des Merisiers, Bât. 701, 91191 Gif-sur-Yvette *Responsable scientifique : Michale Schulz* UR Sols INRA, 2163 Avenue de la Pomme de Pin, CS 40001 Ardon 45075 Orléans *Responsable scientifique : Guy Richard*
Duration	Two years 2010-2011

Summary

Controversy is brewing about the potential greenhouse gas (GHG) savings resulting from the displacement of fossil energy sources by bioenergy, which mostly hinges on the uncertainty on the magnitude of nitrous oxide (N20) emissions by cultivated soils. The life-cycle GHG budget of bioenergy pathways are indeed strongly conditioned by these emissions as related to fertilizer nitrogen inputs during feedstock growth.
This project aims at improving the estimation of N2O emissions from local to regional scales (ie integrated on the feedstock supply area of a bioenergy unit), using biophysical ecosystem models and measurements and modeling of atmospheric N2O in the greater Paris basin. The ecosystem models (in particular for agro-ecosystems) will be parameterized and tested against existing plot-scale data sets and data specifically collected for the purpose of this project on a range of species (annual and perennial). They will be then extrapolated to produce N2O emission maps utilizable by chemistry-transport atmospheric models, from regional to global scales. These models will make it possible to test the "bottom-up" emissions maps, by comparison with the atmospheric measurements carried out on 3 stations in northern France with various catchment sizes, and to obtain independent "top-down" estimations.
The emissions of N2O as integrated at the regional scale, will be used in a life-cycle assessment of representative bioenergy pathways (biofuels, and combined heat and power generation). Effects related to direct land-use changes (and their impact on soil carbon stocks) will be also included in the assessment, based on land-use projections as driven by bioenergy implementation scenarios in France.

Results

1 – Flux and concentrations measurements network

One objective was to carry out high-precision quasi continuous monitoring of nitrous oxide at 3 representative sites and to calculate N2O fluxes with the radon tracer method. The seasonal cycle is attributed to the emission of agricultural soils. N2O emissions from soils during winter months are very small or close to zero. Repartition of N2O emissions of agriculture soils is 54 % of 0.23 g (N2O)/ m2/year for the catchment areas of Gif-sur-Yvette and Trainou station.
Emissions peaks follow the fertilizations in early spring, when soil water content is high and temperature increases. The dryness of soils must limit N2O fluxes.
In Grignon, emissions from cereals (wheat, barley) are up to one order of magnitude higher than over the lignocellulosic crops, with a strong temporal pattern related to the timing of fertilizer application. The resulting spring emission spikes are not recorded under miscanthus and switchgrass, which are not fertilized. The winter emissions, before fertilizer application, are similar between the two types of crops, and of low magnitude because of low soil temperatures.

2 – Context and objectives

In soils, N2O is mainly produced by two microbial processes: nitrification and denitrification. These processes are influenced by several environmental factors such as soil temperature and moisture as well as by management practices such as nitrogen application.
One of the main objectives of this project is to improve the current estimates of biogenic sources of N2O, in particular over the ecosystems in which biomass may be grown for energy purposes.
The two models used are the agro-ecosystem model CERES-EGC and the terrestrial biosphere model ORCHIDEE-CN (O-CN). CERES–EGC performed better than O-CN in most sites, with lower mean deviations and root mean squared error values. For the year 2007, the total emissions by CERES-EGC are 20.4 Gg N-N2O /year accounting for direct emissions after mineral and organic fertilizer application as well as indirect emission from atmospheric N deposition. The total emissions by O-CN for 2007 are much higher and are 95.1 Gg N-N2O/year. Even though the total emissions are largely different between the two models, the temporal and spatial distributions are comparable. The spatial distribution of N2O emissions between the two models presents some discrepancies. However, both models are able to catch regional hot spots which correspond to high intensity agricultural areas.

3 – Atmospheric modeling

Atmospheric transport modeling is a numerical tool linking N2O emissions to N2O atmospheric mixing ratios.
The objective is to simulate the fate of N2O in the atmosphere, using ground-based atmospheric stations to test the atmospheric models and existing emissions maps including those obtained in this project. Atmospheric N2O is simulated at the global scale wwith the LMDz-INCA model, and at regional scale with the CHIMERE meso-scale model.
Many scenarios were used and many results obtained, as described in the final report.

4 – Greenhouse gas balances of bioenergy pathways

In most LCAs of bioenergy chains, N2O emissions from soils are estimated with fixed emission factors expressing a proportionality between N2O efflux and fertilizer N input rate. These factors have a wide range of uncertainty and their worldwide median value has even been questioned.
Estimates of N2O fluxes obtained at regional scale in this project were used in the following case-studies : 1st and 2nd generation biofuels and combined heat and power production from miscanthus and cereal straw.
Comparisons between several studies (ADEME) and results from this project were performed and some difference were obtained, as described in the final report.
Calculated GES fluxes from biofuels production are 10 % to 40 % less to those published by ADEME in the last biofuel-ACV study.

Deliverables

Rapport final

Project publications - Publications liées au projet

Dissertations - Mémoires diplômants :

Boukari, E., 2010. Modélisation des émissions de Protoxyde d'azote en France à l'aide d'un modèle d'agro-écosystème. Mémoire de Master de sciences et technologie, parcours Biosphère continentale, Université Paris 6 – AgroParisTech.
Marionneau A, 2011. Déterminisme des émissions de N2O par les sols en relation avec leur statut hydrique. Mémoire de Master 2 AgroParistech, Sciences et techniques du vivant, 37pp.
Vivien, C., 2011. Fondements et Applications, Evaluation de cadastres d'emissions de par comparaison a des mesures de concentrations en Europe pour l'annee 2009. Mémoire de master1 de Sciences et Technologie de l'UPMC, Mention Sciences de l'Ingénieur, Orientation Mécanique des Fluides.
Prieur, V., 2012. Modélisation du cycle terrestre de l'azote et estimation des émissions de N2O à l'échelle de la France et de l'Europe. Thèse de Doctorat, Université Pierre et Marie Curie, Environmental Sciences, Paris, 2012 (soutenance prévue le 10/1/2012).
Tonneau S, 2011. Mesure et suivi de la teneur en eau des sols par utilisation de sondes de mesure de la teneur en eau volumique. Mémoire de licence professionnelle, IUT de Bourges, Expertise Mesures et environnement, 56p.

Conference proceedings - Communications à des congrès internationaux :

Boukari, E.; Gabrielle, B.; Lehuger, S.; Chaumartin, F. & Massad, R. Generating highresolutioninventories of nitrous oxide emissions from agricultural soils with an agroecosystem model Proc. 5th International N Conference, New Dehli, December 2010 (poster).
Gabrielle, B.; Lehuger, S.; Prieur, V. & Schulz, M. Integration of N cycling and trace-gas emissions in global vegetation models: experience with CERES-EGC and ORCHIDEE Invited conference, COST STSM Workshop, Garmisch, April 2010 (conférence invitée).
Gabrielle, B. & Bessou, C. Impacts of switching from 1st generation to 2nd generation biofuels on GHG emissions from cropland and life-cycle balances GHG Europe workshop on GHG emissions, land use and biofuels - Dublin, October 2010 (conférence invitée).
Gabrielle, B. How to ensure a reliable and sustainable supply of biomass feedstock? Invited Keynote Lecture at the 1st LignoBioTech International Conference, Reims, France, 1 April 2010.
Gabrielle, B.; Prieur, V.; Thompson, R.; Schulz, M.; Schmidt, M.; Boukari, E.; Lehuger, S.; Chaumartin, F. & Massad, R. Fine-scale estimation of biogenic emissions of nitrous oxide using ecosystem models and atmospheric transport models in France. NitroEurope Open
Science Conference, Edinburgh, 2011 (oral presentation).
Gu J., Nicoullaud B., Rochette P, Grossel A, Hénault C, Cellier P., Richard G., 2010.12, Effects of topography and soil type on N2O fluxes from tile-drained cropland in Central France. 2nd Sino-French Joint Workshop on Atmospheric Environment, Orleans, France.
34 Rapport final - synthèse, projet IMAGINE, CONFIDENTIEL
Gu, J., A. Grossel, B. Nicoullaud, P. Rochette, D. J. Pennock, P. Cellier, G. Richard, Nitrous oxide emissions from winter wheat cropland at landscape scale in France, EGU General Assembly, Vienna, Austria, 2-7 Mai 2010 (poster).
Grossel, A., J Gu; B Nicoulaud, C Guimbaud, P Rochette, C Robert, V Catoire, C Hénault, P Cellier, G. Richard, Study of the spatial variability of N2O emissions at the landscape scale in Central France, Nitrogen and Global Change conference, Edinburgh, 11-14 avril 2011
(poster).
Thompson, R.L., P. Bousquet, F. Chevallier, E. Dlugokencky, A. T. Vermeulen, T. Aalto, L. Haszpra, F. Meinhardt, S. O'Doherty, J. Moncrieff, E. Popa, M. Steinbacher, A. Jordan, T. Schuck, and C. A. M. Brenninkmeijer, Global and European scale N2O emissions estimated
using a variational inversion approach. NitroEurope Open Science Conference, Edinburgh, 2011 (oral presentation).
Thompson, R.L., P. Bousquet, F. Chevallier, E. Dlugokencky, A. T. Vermeulen, T. Aalto, L. Haszpra, F. Meinhardt, S. O'Doherty, J. Moncrieff, E. Popa, M. Steinbacher, A. Jordan, T. Schuck, and C. A. M. Brenninkmeijer, Global and European scale N2O emissions estimated
using a variational inversion approach. NitroEurope Open Science Conference, Edinburgh, 2011 (oral presentation).
Thompson R.L., Castaldi S., Santini M., Valentini R., Bousquet P., Chevallier F., Ciais P., and data providers,

Global estimates of N2O emissions: a comparison of top-down and bottom-up approaches, EGU conference, Vienna, April 2011 (oral presentation).

Propositions pour la session 'Towards a full GHG balance from the biosphere. How important are N2O and CH4 emissions in different ecosystems? How difficult is to measure and to model their emission?' de la conférende de l'EGU à Vienne en Avril 2012 :

Estimating agricultural N2O emissions in France: comparison of a spatialised agroecosytem model (CERES-EGC) and a terrestrial biosphere model (ORCHIDEE-CN).(Massad R.S., Prieur V., Lehuger S., Chaumartin, F., Boukari, E. M. Schultz et Gabrielle B.)
Simulations of N2O concentrations for France using ecosystem models, emission databases and an atmospheric transport model. (Massad R.S., Thompson R., Pison I., Prieur V., Lehuger S., Chaumartin, F., Boukari, E. M. Schultz et Gabrielle B.)
Synthesis of results of the IMAGINE project (Gabrielle B and all project participants)

Peer-reviewed papers - Articles scientifiques :

Thompson, R. L., Bousquet, P., Chevallier, F., Rayner, P., and Ciais, P.: Impact of the atmospheric sink and vertical mixing on nitrous oxide fluxes estimated using inversion methods, J. Geophys. Res., 116, doi:10.1029/2011JD015815, 2011.

Submitted – Soumis :

Gu, J., Bernard Nicoullaud, Philippe Rochette, Agnès Grossel, Catherine Hénault, Pierre Cellier, Guy Richard. Effects of topography and soil drainage on nitrous oxide emission from tile-drained fields in central France, soumis à Nutrient Cycling in Agroecosystems.

In preparation - En préparation :

Gabrielle B., Prieur, V., et al. Comparison of O-CN and CERES-EGC models for the simulation of nitrous oxide emissions from cropland. In preparation for Biogeosciences.
Gabrielle, B., Gagnaire, N., et al., Life-cycle assessment of biofuel pathways in Ile de France based on ecosystem modelling, including direct and indirect land-use change effects
Gu J, Nicoullaud B, Rochette P, Grossel A, Hénault c, Cellier P, Richard G Influence of topography and soil type on nitrous oxide emission from tile-drained fields in central France
Lopez, M, Schmidt, M et al., Estimation of nitrous oxide emission in France using atmospheric nitrous oxide and radon-222 measurements . in preparation
Luyssaert, S., …. Bousquet, P., Ciais, P., Thompson, R.L. et al., The European CO2, CO, CH4 and N2O balance between 2001 and 2005, a synthesis from the RECAP project, inpreparation.
Massad R.S., Prieur V., Lehuger S., Chaumartin, F., Boukari, E. M. Schultz et Gabrielle B. Regional estimation of N2O emissions from cropland in France: comparison of an agroecosytem model (CERES-EGC) and a terrestrial biosphere model (ORCHIDEE-CN).
Massad R.S., Thompson R., Pison I., Prieur V., Lehuger S., Chaumartin, F., Boukari, E. M.Schulz et Gabrielle B. Simulations of N2O concentrations for France using ecosystem models, emission databases and an atmospheric transport model.
Thompson R.L., Castaldi S., Santini M., Valentini R., Bousquet P., Chevallier F., Ciais P., et al., Importance of developing regions to global N2O emissions, in preparation

Suite du projet :

Le projet européen Logistec a été accepté et constitue pour partie une suite aux point 2 et 4 du projet Imagine.

Contact

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