Section 1: Summary

Summary of project context and objectives

GHG-Europe is fully dedicated to improve our understanding and capacity for predicting the impact of natural and anthropogenic drivers on European terrestrial carbon and budgets of CO_2, N_2O and CH_4.

The terrestrial biosphere has absorbed 13 % of the fossil fuel emissions of EU-25 over the last decade (Schulze *et al.*, 2010). This net carbon sink is almost compensated by N_2O and CH_4 emissions from agriculture (Schulze *et al.*, 2010). However, these results strongly rely on models which have not been validated against the wealth of observational data, suffer from inconsistencies in the time horizons and types of uncertainties considered as well as from lack of integration between CO_2 measurements and other greenhouse gases (GHGs). Improved quantification of the annual to decadal variability in the European terrestrial C and GHG budget requires

1. the full exploitation of all available data streams (WP1, 2 and 3 of GHG-Europe),
2. much stronger data-model integration (WP2-5 of GHG-Europe),
3. consistent temporal and spatial domain coverage (WP1 of GHG-Europe) and
4. complete consideration of error propagation at all calculation steps (WP4, 5, 7 of GHG-Europe).

The land use sector can play an important role in mitigating climate change. However, biological systems have their intrinsic dynamics, and interact with climate change in a complex way that is not completely understood. This makes climate change mitigation measures in agriculture, forestry and other land uses more complicated and uncertain than in any other human sector. Ultimately, the scientific challenge is to determine how, and to what degree, the carbon cycle and GHG emissions in terrestrial ecosystems can be managed. This requires a much improved understanding of the responses of biogeochemical processes in ecosystems to changes in natural and anthropogenic drivers (WP2-5 of GHG-Europe) and the implementation of the responses to assess future vulnerability of the GHG budget (WP6 of GHG-Europe).

Natural and anthropogenic drivers of C and GHG fluxes in ecosystems are intimately linked. Considerable progress in the attribution of the variability in C and fluxes of CO_2, N_2O and CH_4 to multiple interacting factors by GHG-Europe can be expected by

1. the collection and synthesis of the fast growing observational evidence of ecosystem response to individual drivers,
2. improved representation of climate variability AND land use and management in ecosystem models, and
3. a coherent approach to address the interactions between drivers from local to continental scales (implemented in all WPs of GHG-Europe).

The future vulnerability of carbon pools and risks of positive feedbacks in the climate-carbon system are assessed by scenario analyses with biophysical models and by integrating feedbacks with socio-economic changes and EU climate and land use policies. GHG-Europe uses a bidirectional interaction with stakeholders to provide scientific advice targeted to the emerging needs of the UNFCCC process and for implementing post-2012 climate commitments in Europe (WP6 of GHG-Europe).

Work performed since the beginning of the project and main results so far

The work performed since the beginning of the project and main results are described along the 4 overarching scientific objectives of GHG-Europe.

1. Quantify the annual to decadal variability of CO_2, N_2O and CH_4 budgets of terrestrial ecosystems in Europe.

A prerequisite for modelling GHG budgets is a consistent temporal and spatial domain coverage of critical drivers. The development of standardised gridded fields of natural and human drivers for EU27+ from about 1900 - 2010 and projections until 2050 or 2100 was therefore in the focus of the work performed for the first project period.

Standardised gridded fields for the EU-27 plus Switzerland are available at 0.25 ° resolution for the main climatic variables (1901 - 2010; 2010 - 2100), nitrogen deposition (1850 - 2050), land use and land use change (1900 - 2010) and forest age class distribution (1950 - 2010). Agricultural management since 1960 and socio-economic driver maps are in progress. The driver fields are accessible to the wider research community upon request.

During the first reporting period, a preliminary comparison of terrestrial carbon fluxes over Europe by top-down and bottom-up approaches has been performed. The datasets from 5 atmospheric inversions and 10 Terrestrial Ecosystem Models (TEM) are used for comparisons. They have a variety of spatial resolutions, from 0.25 x 0.25 ^{o} to 4 x 5 ^{o}, and data intervals, from weekly to annual. Preliminary analysis with 5 atmospheric inversions and 5 TEMs show the large difference in trends among the areas (Fig. A). For example, North Europe indicates negative fluxes with similar size among all the data, although south Europe shows contrary signs of fluxes between approaches. The detailed analysis is in progress.

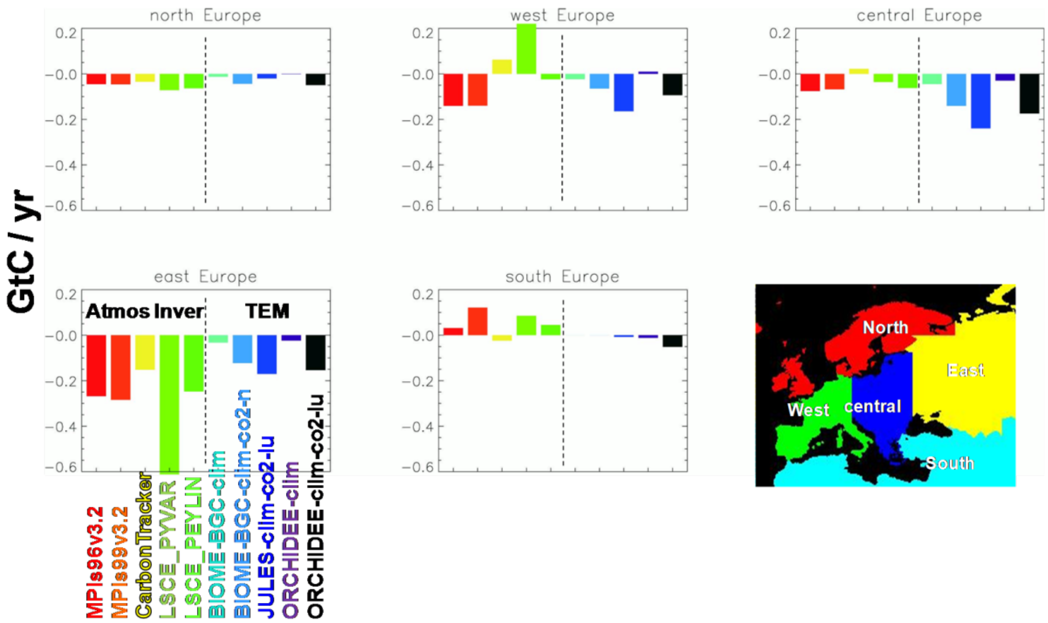

Figure A: Accumulated terrestrial carbon fluxes in 5 regions over Europe.

GHG-Europe contributes the assessment for the European continent to the international synthesis of global CO_2 fluxes RECCAP, which is coordinated by the Global Carbon Project.

2. Obtain a better and more comprehensive understanding of the terrestrial carbon cycle and responses of CO_2, N_2O and CH_4 fluxes to the variability in natural and anthropogenic drivers (climate, N deposition, land use, management) and pressures (global markets, European climate and land use policies) for European forest, grassland, cropland, peatland and shrubland ecosystems.

The GHG-Europe project served as a network and platform for many synthesis activities. There were intensive efforts and activities via data collection and workshops to harmonise and synthesise site level information on GHG fluxes in peatlands, land use change for bioenergy (Don *et al.*, in press), the effect of N deposition on carbon and GHG fluxes in forest soils (Janssens *et al.*, 2010) and post-fire and litter quality impacts on carbon in Mediterranean shrublands (Martí-Roura *et al.*, 2011, Montané *et al.*, 2010). Nine GHG-Europe workshops were organised in which not only GHG-Europe partners participated, but also many scientists from outside the project. From this collaboration new insights new insights into management and N deposition effects of carbon and GHG balances have been derived. A comprehensive meta-analysis on land use change effects on soil C has been published (Poeplau *et al.*, 2011). Carbon response functions confirmed the hypothesis of “slow in fast out”. For example, the establishment of croplands caused rapid soil carbon losses (equilibrium after 17 years), while there was only a slow and long-term-dependent accumulation of soil C, if croplands are converted back to forests or grasslands (equilibriums not reached within 120 years; Fig. B).

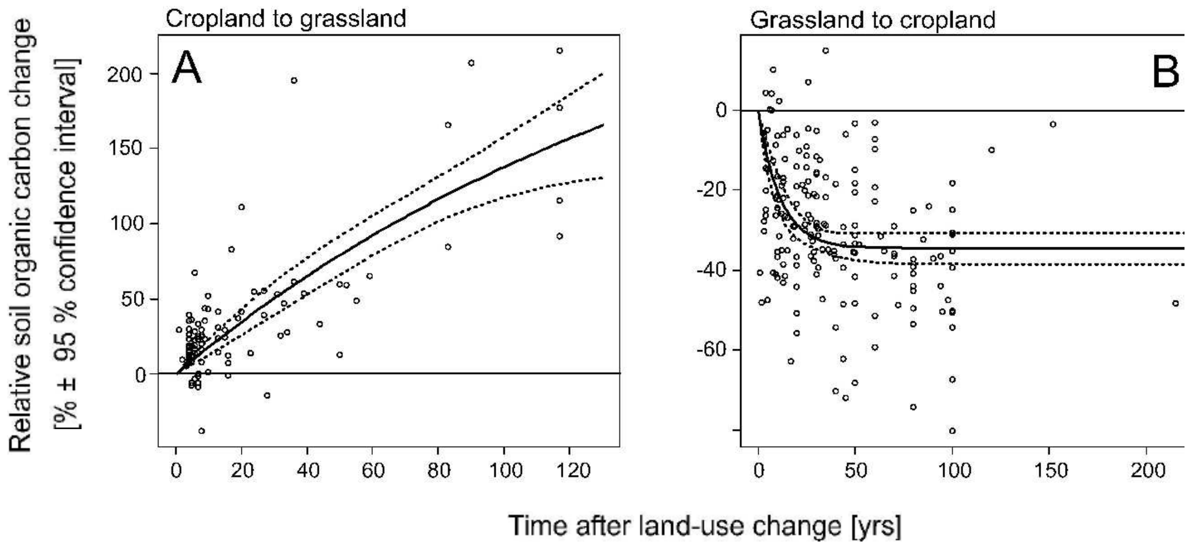

Figure B: Examples of response functions of soil organic carbon changes after land use change (Poeplau *et al.*, 2011).

Greenhouse gas flux measurements have been started in undersampled regions of Europe: a peaty catchment in Scotland, Mediterranean shrublands and mixed beech forests under a strong management intensity gradient in Romania.

Greenhouse gas flux measurements and driver data collection is ongoing in 6 data rich regions of Europe. The first budgets of lateral GHG fluxes at farm-gate have been established.

3. Identify the carbon pools and GHG processes most sensitive and vulnerable to changes in individual drivers and in driver combinations, and the associated risks of positive feedbacks with climate change in the 21st century.

For the purpose of sensitivity and vulnerability analyses, modelling protocols have been established and agreed upon among all project partners. The protocols have been implemented to derive the driver fields and to set priorities for data collection in the 6 data rich regions.

Seven sectoral models have been evaluated against site level data for CO_2, N_2O and CH_4 in cropland, grassland and forests. Every model showed specific strengths and weaknesses, but overall performance for annual GHG budgets was good. Modelling the correct timing and magnitude of hot moments of GHG fluxes at daily resolution remains a challenge.

The first attribution experiments of forest and agricultural management effects on GHG fluxes with sectoral and generic ecosystem models were performed (e.g Ciais *et al.*, 2011). For example, attribution of N_2O fluxes to climate, soil and N fertiliser identified a heterogeneous pattern in cropland, driven by soil properties and climate with variable response to N fertiliser, but a largely homogeneous, strong response of N_2O fluxes to N fertiliser in grassland (Dechow and Freibauer, subm.).

4. Assess, in economic, societal and environmental terms, the impact of possible post-2012 strategies / policies on future carbon pools and CO_2, N_2O and CH_4 fluxes in Europe and possible synergies by coordination of different land use related policies and of cross-sectoral climate policies.

An economic and integrated policy assessment is being carried out. Work so far focused on model integration and adaptation. An integrated framework for the projection of LULUCF CO_2 emissions and removals has been established. The framework addresses emissions and removals occurring through activities like forest management, afforestation and deforestation. The algorithms for estimating emissions and removals from grassland and cropland management are under development and will be tested soon. Two basic policy scenarios are established: the baseline scenario driven by GDP, population and bioenergy demand without the recent climate policy assumptions and the reference scenario, which considers the EU's climate and energy package. Harmonisation of data, models and assumptions is ongoing.

Publications

So far, 87 publications produced in GHG-Europe or associated with activities in GHG-Europe have been accepted by peer-reviewed journals (72 published, 15 accepted).

Expected final results and potential impact and use

GHG-Europe will significantly improve the prognostic capacity of state-of-the-art ecosystem models by systematic multi-site, multi-scale validation and Bayesian calibration and the improved representation of ecosystem response to natural AND anthropogenic factors. The project results will quantitatively and qualitatively provide new insights for a better foundation of decisions in the international climate negotiations.

GHG-Europe will provide the scientific basis for "factoring out" natural variability and past management effects, which are at the core of the UNFCCC negotiations.

The results will also allow robust assessment of the consequences of political choices in the post-2012 negotiations regarding baseline methods and accounting rules for C stock changes in the LULUCF sector.

In view of the European implementation of post-2012 climate policies, GHG-Europe will provide the scientific foundation to assess the risk for compliance due to uncertainties and vulnerability of C stocks to climate change.

Project website information

The project website address: www.ghg-europe.eu.