# Terrestrial Carbon Cycle Management Project (TCCM-P)

## 1. Background

Human intervention in terrestrial ecosystems has been occurring for thousands of years and has impacted the global carbon cycle. Accumulated emissions from pre-industrial emissions from land conversion are estimated to be 320 GtC. However, only in the postindustrial era (last 200 years) have anthropogenic changes in carbon fluxes become comparable in magnitude with the major natural fluxes in the global carbon cycle. During that period fossil-fuel emissions amounted to 270 GtC, while 136 GtC were emitted as a result of land-use change, predominately from deforestation. Approximately 115 GtC were absorbed by terrestrial ecosystems between 1850 and 1998. Today social awareness of the substantial risks related to climate change from emissions-induced increases in atmospheric greenhouse-gas (GHG) concentrations is increasing. A continuation of today's GHG emission path is likely to lead to dangerous interference with the climate system and consequently lead to adverse effects on human welfare.

Enhanced land based long-term storage of carbon in soils, trees and geological formations provide a critical intervention by which humans can modify the carbon cycle and potential radiative forcing. Methods include the preservation of existing carbon stocks by avoiding deforestation, reducing land degradation, reforestation, afforestation, altered agriculture and forest management practices, altered consumption patterns, and fossil fuel substitution. Analysis of multi-GHG abatement measures indicates co-benefits and/or trade-offs for carbon-based mitigation options. The economic potential for GHG management at the terrestrial ecosystem level could be substantial for both short- and long-time periods. Low-cost greenhouse gas emission reductions or offsets could provide near-term implementable strategies while allowing time for the development of longer term energy related innovations. At the same, time terrestrial ecosystems can be associated with the hazards of non-linear developments. Greenhouse gases may inadvertently be released if a carbon sink is perturbed, damaged or destroyed. Thus, patterns of the terrestrial carbon cycle cannot be only associated with gradual changes, but also with high uncertainty and risks, including extreme and unanticipated events.

The TCCM-P is designed not only to focus on the identification of points of intervention in the global carbon cycle for mitigation purposes, but also to contribute to the assessment of critical vulnerabilities and their implications for sustainable terrestrial ecosystem management. The project will primarily make use of economic assessment

<sup>&</sup>lt;sup>1</sup> Endorsed by the GCP Science Steering Committee, 2005

tools and biophysical models, but will also look into the wider human dimensions of managing the global carbon cycle through a number of other social science tools.

## 2. Goals

The goal of the proposed project is to (1) identify and (2) quantify points of intervention in the terrestrial carbon cycle in a consistent manner with the energy and industrial sectors in order to safeguard sustainable development of the coupled carbon-climate-human system. The evolution of the global carbon system through the 21<sup>st</sup> century and beyond will be the outcome of a three-way coupling among natural processes, anthropogenic drivers, and human responses.

# 3. Research proposed under the TCCM-P

The Terrestrial Carbon Cycle Management - Project (TCCM-P) aims at broadening our understanding of how to manage terrestrial ecosystems under global change. In particular, the adoption of environmental technologies mitigating anthropogenic greenhouse-gas (GHG) emissions via management of emissions, sequestration and offset processes in the agricultural and forestry sectors will be appraised in a context of various development scenarios. The project aims at developing a transparent toolbox that can be trusted, understood, and shared by stakeholders, as well as sharing scientifically validated data.

Greenhouse-gas mitigation measures in agriculture and forestry are already part of the currently existing carbon markets but are limited in scope due to information shortages and perceptions. If the contribution of biospheric measures could be expanded in the second commitment period negotiations, these measures could turn out to be instrumental in attaining short- and long-term climate-mitigation goals in an efficient manner, contribute to sustainable farming and also to become a major driver of how terrestrial ecosystems are managed. The landscapes of today could dramatically change due to the introduction of incentives to mitigate climate change. A thorough, integrated economic and environmental assessment of the economic and sustainable potentials of these measures has yet to be carried out on broad/global scales. The TCCM-P project seeks to develop appropriate analytical tools for policy assessment of mitigative and climate reactive practices in a wider framework of sustainable development. The originality of the TCCM-P project is its consistent combination of sector-specific tools cutting across a number of science and policy fields. Thereby, it aims at quantifying impacts of sectorspecific strategies in climate, energy, agriculture, forest and nature conservation policies. Furthermore, the identification and quantification of a number of potential ancillary benefits and possible negative externalities of policy actions will be carried out.

Purposefully induced long-term storage of carbon on land through increase of dead or living biomass or substitution of living biomass for fossil fuels provides critical interventions by which humans can modify the dynamics of the carbon cycle and, to some extent, influence the current upward trend of atmospheric carbon concentration. Biomass-based mitigation options include:

• Reduction of carbon emissions from land disturbance (e.g., deforestation avoidance, fire and pest management, avoided destruction (drainage) of peat

forming wetlands) and the increased carbon sink capacity through land-use change, e.g., reforestation and afforestation.

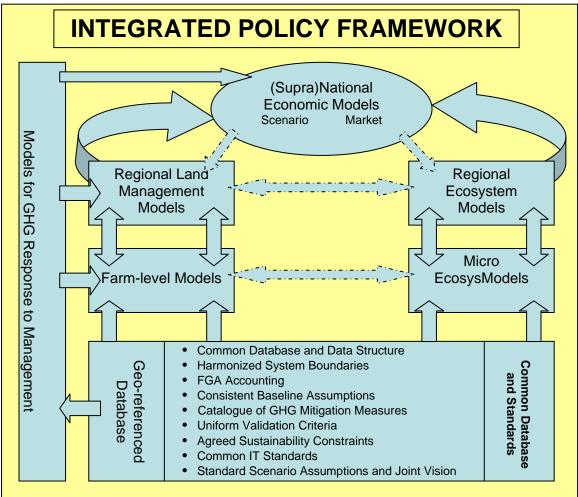
- Increased sequestration rate of carbon in the ecosystems by altered land-use practices (e.g., no-till agriculture and improved forest management) and increased sequestration in the entire life cycle of biomass based products through altered use patterns and consumption.
- Substituting fossil fuels with biomass and possible engineered disposal of the captured carbon in geological and oceanic repositories.

In addition to the effects on greenhouse-gas mitigation, carbon sequestration activities will carry a number of ancillary benefits and/or collateral damage to the environment, economy and to socially valued amenities, all of which will determine the viability of a particular mitigation measure. Thus, economic analysis of carbon benefits should preferably be carried out in an environment of polyproduction (e.g., optimizing for timber, agricultural production, biodiversity, environmental quality and carbon values) given a number of environmental and socio-economic constraints. One important example would be monitoring area expansion of biomass plantations to ensure local, regional and global food security and biodiversity.

By their very nature, land use, land-use change, and forestry (LULUCF) activities occupy space. Starting with a thorough bottom-up analysis and modelling of the emission balance of agriculture, forest and livestock activities as a function of technologies, the TCCM-P approach seeks to integrate farm-level and forest-plot models with regional and national models for an assessment of the potential economic and environmental impacts of policy change. A multifaceted approach across different scales should guarantee robustness and consistency in the assessment of sustainable and cost-effective GHG emission mitigation policies. The bottom-up approach on the one hand will inform more aggregate models and facilitate the validation of aggregate results and, on the other hand, will help illustrate behavioral change on the micro scale that economy-wide policies seek to influence. Thus, results from the modelling exercises will become more tangible for non-expert users.

The proposed analysis is geographically nested, which guarantees that bottom-up results can readily be integrated in analytical tools that operate on global scales. Figure 1 illustrates the interaction between the different scales of analysis, the models used at each level and the interactions between them. Right from the start (see box at the bottom of Figure 1), a common database will be made available to all partners and, with some restrictions, to the global public. Common GHG-accounting and cost-accounting standards will be developed providing input to detailed biophysical models assessing GHG - mitigation effects due to management change as a consequence of technological adoption. Likewise, system boundaries and baselines all the way to scenario assumptions will be harmonized. The next two blocks, as depicted in Figure 1, are about micro-level modelling with individual farm models on the agricultural side and plot models on the forestry/natural ecosystem side. The results from the farm models will be checked for consistency with results from regional (sub-national) models. In addition, the interplay between these two models will help to quantify the GHG-mitigation implications of

agricultural policies. Results from forest/ecosystem-management models operating on a regional scale will be downscaled to grid level in order to integrate with biophysical models and validate results from the stand-level management models (e.g., gap-models or hybrid models). Results from the regional (meso-scale) models from the respective sectors will then feed into the national or supranational economic models (e.g., FASOMGHG), which will be used for aggregate analysis augmented by market effects. The agronomics and carbon implications of management change in the agricultural sector will be quantified with crop growth models (e.g., EPIC, CENTURY, WAFOS, and DNDC).



Results from the TCCM-P project are designed such that they can be readily incorporated or directly linked to other social, economic or biophysical-chemical models. TCCM-P components are modular and exchangeable. This means that any model component, e.g. the plant growth model, can be exchanged for another or be simultaneously applied for reasons of uncertainty assessments. By design, such a modular approach will provide for a large basis for participation by partner research groups. Analysis of complex interwoven systems of risks (e.g. between natural and humaninduced activities) is needed when appraising management options of the terrestrial biosphere. Risk-based analytical tools will be employed to illustrate strategies to manage and hedge such risks. One example of a risk-based study would be the assessment of vulnerability management of large carbon stocks in a wider framework of climate-risk management.

### 4. Relevance to the GCP Implementation strategy

Work within the TCCM-P will contribute to Theme 3 of the GCP – Carbon Management. Since carbon management has to build on other themes, the assessment of intervention options in the global carbon cycle will naturally build on the outcomes of Themes 1 and 2. The project will employ and compare a variety of global/regional process-based models on the biophysical side and validate those against empirical data. Most global biophysical models are currently not able to model management change and therefore only a small selection of models will be appraised at the beginning with the potential to engage a wider set of analytical tools later. Model uncertainty appears to be a crucial impediment for the adoption of land-based activities. The application of a number of different models in a comparative model study will help to elucidate inter-model uncertainties.

## 5. Leadership

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### 6. Contributing Research Groups

A part of the proposed research is partly financed by the European Union under its 6th Framework Program. There are 13 participating organizations involved in this European consortium. An "Integrated Study for Terrestrial Carbon Management of Asia in the 21st Century" is funded by the Ministry of the Environment, Japan. The GCP's URCM Initiative, which is a comparative and historical approach to urban, regional and global carbon footprints, their determinants, trajectories and management opportunities, will contribute insights into the "human dimensions" of terrestrial carbon management. In the United States there are a number of experienced groups who have indicated strong interest in the TCCM-P and have committed to contribute to the TCCM-P. In the course of the project, it is expected that collaborators from all continents will be engaged to carry out truly global studies.

## 7. Timetable

Regional results are planned to be published by end of 2006. Global results should come on-line by 2007. The majority of research reports and products are planned to come out during 2008.

Furthermore, the TCCM-P will explore the possibility of new contributions in key regions of the world during 2005. A number of workshops are envisaged to be held with the aim to foster regional networks within the global framework.

## 8. Plans for funding

Funding from research grants in the EU, US and Japan currently exist and additional funding proposals are planned. In particular, funding for the regional networks appears as a critical issue and will be addressed during the course of the project.

#### 9. Expected Outcomes/Products

- Model cluster for integrated assessment of the economic and bio-physical implications of managing terrestrial eco-systems for climate mitigation purposes.
- Review and broad assessment of mitigation practices involving land including their technical, economic and implementation potential.
- Executive Reports (special journal issue, book, conference etc.) with respect to the role of the biosphere as cause and as a means to mitigate climate change.