Data and models in the reporting of the GHG fluxes from soils disturbed by land use and climate change - WG3

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Background

Climate warming, due to an increased release of greenhouse gases (GHG) into the atmosphere following energy and food production, waste management and land use changes, may increase the risks of serious environmental hazards (Watson *et al.* 2001). For nations, mitigation of such risks will require significant reductions in anthropogenic GHG emissions. As a starting point for international collaboration in the mitigation activities, reliable inventories of emissions were agreed in the United Nations Framework Convention of Climate Change (UNFCCC) in 1992, and in the Kyoto Protocol thereafter (1997). The inventories should follow internationally accepted guidance (Houghton *et al.* 1997, Penman *et al.* 2000, Penman *et al.* 2003) by International Panel on Climate Change (IPCC). While the emissions from fossil fuel combustion for energy production can be calculated with reasonable accuracy, estimation of emissions originating from biogeochemical cycles, disturbed by land use is more challenging.

Reporting of GHG emissions due to Land Use and Land Use Change (LULUCF) is not straightforward. The IPCC Good Practice Guidance reports (Penman *et al.* 2000, 2003) have suggested three methodological tier levels for estimating emissions and removals. For land use based estimates Tier 1 employs IPCC default emission factors per area and usually activity data that are spatially coarse, Tier 2 uses the same methodological approach as Tier 1 but emission factors are country-specific and high resolution land area data are used. Tier 3 uses higher order methods including models and inventory measurement systems, and high resolution activity data. Countries are encouraged to use the two higher tiers in their inventories, whenever possible.

Biogeochemical models in GHG reporting, the framework for WG3

Tier 3 reporting relies on models and high resolution data on soil types and land use categories. Running of a soil model is only possible when adequate data are available as model parameters.

Participants of COST E21 meet humic layer over podsol in a Finnish forest site Hyytiälä, central Finland. Photo Jukka Alm, 2004.

All models are simplifications from reality and their estimates are uncertain. Consequently, the quality of model output must be verified against measured data, and the uncertainty of the estimates quantified. Quality and quantity of available information on land use and GHG emissions related to land use may vary greatly in various countries. While some EU member states must use the IPCC default emission factors in their NIR submissions, some countries have more specific data and are able to use a higher Tier. Collecting of land use specific, regionally relevant data are extremely costly.

Figure 1.
Use of natural resources in Finnish landscape: A former clearcut to the left from the "central divide" where new forest growth is filling the gaps. To the right from the divide peatland drainage has enhanced tree growth and the forest area appears striped due to the drainage ditch network. Forest roads with looping end were built for the harvesting.
Photo Jukka Alm, 2002.

Figure 2.
Peat harvesting in Joensuu region, eastern Finland. Milled and sun-dried surface peat is collected in the middle of the strips between the drainage ditches. From there the peat is collected to stockpiles to wait for transportation to the furnace of a power plant. *Photo Jukka Alm, 2004.*

COST 639 WG3 needs to communicate with the previous and other relevant research activities. Soil types and land use vary among countries for geographical and historical reasons. Thereby also the soil related information and its availability greatly varies. The Action needs to point out the most important "hot spots" of land use: "The target is to identify site types and land management practices, where the stock changes are most likely to happen, because these are the areas where monitoring efforts need to be concentrated" (MoU, http://www.cost.esf.org/index.php?id=205&action_number=639). These important site types may prove difficult in terms of soil modeling. For example managed organic soils are strong sources of GHG's in the boreal parts of Europe (Alm et al. 2007, and references therein), but existing biogeochemical models such as CO_2Fix, DNDC or Century are designed for soils not accounting for the influence of water table within the organic layer or the freeze-thaw cycles that are important for non-CO_2 GHG's CH_4 and N_2O. Furthermore many of the models in use today are designed for ecosystems in temperate climate conditions. Recently a modeling system called

GEFSOC for producing regional C stocks and stock changes was introduced (Milne et al. 2007, Batjes et al. 2007). Such large scale systems may help in GHG inventories in the future, if adequate data on soil characteristics and land use activity can be provided.

Activities in WG3 are divided in two main areas: Monitoring and Simulation models. The monitoring part considers soil sampling in order to recognize the contribution of hot spots currently underrepresented in the national monitoring schemes. The work on simulation models should review the usability of soil models, identify needs for improvement of those models, assess the uncertainties of model predictions, and communicate with researchers developing regional upscaling of the soil models. Climate warming may increase risks for C and N losses. A further task for WG3 is to consider if European data are usable for risk assessment. All activities in WG3 depend on strong statistical expertise.

Monitoring

Best possible knowledge on land use is found in various national inventory systems and databases, such as National Forest Inventories (NFI). In addition to forest parameters, NFI's with spatially systematic sampling schemes can produce activity data (land areas) also for land use other than forest management. However, the taxation methodologies vary between countries. Further, the knowledge on soil C and N pools and GHG fluxes may be distributed among specialists representing different disciplines. For example in Finland, the reporting activities are coordinated by Statistics Finland, which cooperates with e.g. Technical Research Centre of Finland (VTT), Finnish Forest Research Institute, Finnish Environment Institute,

Figure 3.
Peatland forest floor after harvesting of the trees and soil mounding for regeneration. Drainage ditches collect the released soil solids and nutrients into a sedimentation pool. The water in the pool are flooded on a buffer field established for the protection of watercourses from the effluents. *Photo Jukka Alm, 2006.*

Figure 4.
Coastal forest and remains of a farm after a severe forest fire in Croatia. Photo Jukka Alm, 2004.

Agrifood Research Finland (MTT). Besides the NFI data, data registers of the Information Centre of the Ministry of Agriculture and Forestry and the total land area statistics of the National Land Survey of Finland are utilized (Statistics Finland 2006).

There are ongoing activities that can help in improving GHG monitoring and reporting within the EU. From the list we have identified we only show here an excerpt. COST Action E43 work progresses in harmonizing the European NFI systems (http://www.metla.fi/eu/cost/e43/reports.html). Currently, the Institute for Environment and Sustainability (IES) of the JRC is starting a study "Climate change impact and carbon sequestration in European forests" to improve the greenhouse gas reporting activities of LULUCF especially in the forestry sector (http://forest.jrc.it/). They also coordinate the Forest Focus project BIOSOIL (http://europa.eu/scadplus/leg/en/lvb/l28125.htm) that collects and analyses forest soil data. IES has outlined a sampling strategy (Stolbovoy et al. 2007) for certifying the organic C stock changes in mineral soils. Research on mineral soils has produced summaries of topsoil C content in a form of a map (Jones et al. 2005), but it could be improved concerning organic soils especially abundant in the boreal zone. Two major EU research programs, CarboEurope-IP (http://www.carboeurope.org/) and NitroEurope-IP (http://www.nitroeurope.eu/) are working on C and N cycles and their contribution to the European GHG balance, and focusing also on agricultural lands. These and other information need to be collated in terms of needs by GHG reporting for all the LULUCF sectors and land use forms.

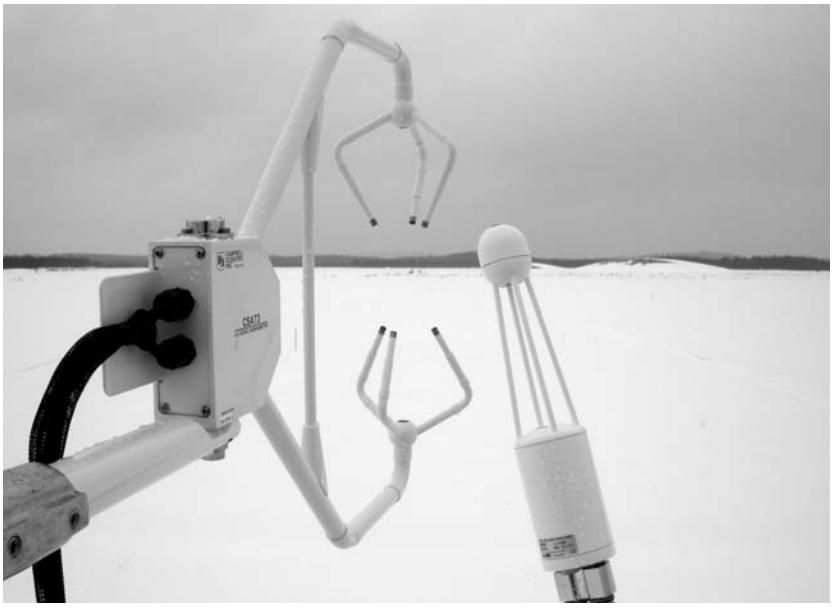
According to the MoU, COST 639 will investigate

1. the probability of C and N stock changes within a certain type of land use,
2. the extent of stock changes as a consequence of land-use change, and
3. the impact of ecosystem disturbances on stock changes.

Bellamy et al. (2005) reported a possible recent loss concerning all soil organic C in England and Wales. Perception of the stock changes with monitoring is difficult because of large spatial variability in soil constituents. The results from large scale soil monitoring programs such as BIOSOIL will give important information whether the resolution is good enough for observing the small temporal changes in soil C and N stock, and if the spatial resolution is good enough to reveal the "hot spot" features in land use as determined by WG1 and WG2. In addition, COST 639 needs to evaluate how important the hot spot emissions may be for the country-scale and EU level GHG inventory results.

For the important land use forms and soil types, the recommendations for methodology to be used in soil sampling for key soil types and land uses will be among the outputs of WG3. As the IPCC guidance is different for mineral soil sites and organic soil sites (Penman et al. 2003), our recommendations shall make similar distinctions concerning the stock estimates and GHG emissions.

Principally the changes in C or N stocks are small with respect to the stock sizes. This is especially true in organic rich soils such as peatlands. An essential part of soil monitoring methodology is to understand the processes involved in soil organic C stock changes (Dawson & Smith 2007), and their contribution to the uncer-



Measuring soil CO_2 release in a winter day at a peat extraction field in eastern Finland. Stockpiles in the background store the peat milled from the surface during the previous summer.

tainty. Important issues of uncertainty are the variability in measurements and analyses and lack of data in specific areas (Dawson & Smith 2007). Information of the relevant soil processes from all over Europe and different land use types can be expected from researchers operating in national programs and in the multinational EU Integrated Projects CarboEurope and NitroEurope.

WG3 will examine how process-based models are currently being used in national inventories for C & N stocks for inventories of GHG fluxes associated with LULUCF. The WG3 will evaluate the quality of the modeling work, taking into account the transparency of the methods but focusing on quantifying and analyzing the uncertainty of the modeling results.

Simulation models

Simulation models can be used for 1) Explaining observed changes, 2) Predicting future changes, 3) Evaluating land use and management options. Models could also form an elementary part of GHG flux calculation for reporting (Alm *et al.* 2007, Milne *et al.* 2007). Agricultural and forest soils are most important managed soils. Stock changes of C and N in mineral soil types and GHG fluxes in organic rich soils are of interest and must be reported there. With that in mind GIS-coupled models such as PnET-N-DNDC have been applied for creating estimates of N_2O and NO emissions across Europe (Kesik *et al.* 2005). The reliability of large-scale regional estimates is subject to how adequate the parameters are and how well the soil characteristics and regional land use patterns are known. European land mass is diverse and the soil types and climatic conditions vary greatly. Therefore, the usability of models has to be inspected.

Models are always simplifications of the system they mimic. It is crucial that the simplified processes and flows are relevant for the questions posed for the model. Usability of biogeochemical models can be tracked to several sources, including the complexity of the system, and data availability for verification (van Oijen *et al.* 2004). The following questions give an idea of how the models should be evaluated:

- Do we know all (relevant) matter flows?
- Do we have data for all the relevant flows?
- Do we have enough information on the mechanisms and controls?
- Are we properly using the information that is available?
  - Most current biogeochemical models only assess parts of the complex atmosphere-vegetation-soil biological, physical and chemical systems.
  - Are only the relevant parts included in the model?
  - Are the key feedbacks implemented?

Risk analysis

Soil C and N stores may be compromised by 1) Land use changes and 2) Consequences of climate warming. Land use may change the capacity of ecosystems to harbour organic matter, and changes in climatic controls may change the balance between primary production and decomposition of organic matter. The probability of catastrophes can increase, introducing more forest fires and insect outbreaks in a warmer world.

Risk analysis for the behavior of ecosystems can be a complex task, but fire is definitely a common and possibly increasing risk. We need to communicate with JRC/IES, who have environmental soil risk assessment projects underway (http://eusoils.jrc.it/themes.html). Among other risks, fire is already responsible for large losses of aboveground C in the Mediterranean countries and may be in the future increasingly so also elsewhere in Europe. That has led to the establishment of the European Forest Fires Information System (EFFIS; http://effis.jrc.it/Home/).

WG3 plans to evaluate the ways in which risk assessment is currently being carried out and how it could be improved. The risk assessment question is certainly more complicated for environmental risks than for those directly related to economical activities. In the first place WG3 aims to collect information on work in European countries on fire risk assessment, but a coordinated approach for the work in WG3 on risk assessment in general, i.e. assessing the modeling capacity to deal with any form of risk is needed.

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