

## Final report

### International workshop on Development of Models and Forest Soil Surveys for Monitoring of Soil Carbon, April 5-9, 2006, Koli, Finland

#### Summary

This workshop on 'Development of Models and Forest Soil Surveys for Monitoring of Soil Carbon' took place in April 5-9, 2006 at Koli Heritage Centre in Finland. The objective of the workshop was to assess current methodological development on soil carbon monitoring methods applicable for large-scale inventories. The workshop evaluated and discussed possibilities to apply existing, well-validated soil carbon models, current soil surveys, knowledge on the spatial variation of soil carbon and sound statistics to monitoring changes in soil carbon on regional scale. Total number of participants was 33 of which 4 were invited keynote speakers. In addition to the keynote presentations, other 14 contributed presentations within three different sessions and 5 presentations in modelling party were given in the workshop. Sessions of the workshop were focused on

- National soil surveys in carbon monitoring - possibilities to improve current methodologies
- Models in estimation of decomposition and soil carbon budget
- Combining models and soil surveys - advances in development of soil carbon monitoring programmes

and the modelling party was aiming to evaluate how suitable state of the art soil models are for estimation of regional soil carbon stock changes.

Major outcome of the workshop was realized as increased common understanding on possible role of the soil C models in large scale carbon inventories. There are several soil models that are already applied and tested to be valid and applicable for large scale soil C inventories. However, soil models deviate in details, in needs for input data, in soil layers accounted and in soil processes included. In general, the selection of the model for a large scale inventory is guided by availability of the input data. Simple decomposition models that can predict average changes in the soil C stock without detailed description of the stand specific soil processes are most appropriate for national inventories, since their needed for input data can be fulfilled.

This workshop has websites that were established before the meeting and will be maintained after the meeting at [www.metla.fi/tapahtumat/2006/soil2006](http://www.metla.fi/tapahtumat/2006/soil2006). All presentation and posters of the meeting as well as abstracts of them are available from that website. Participants of the meeting agreed to write a joint paper as an outcome of the modeling party of the workshop. The aim of the paper is to review seven soil models (Century, Forest-DNDC, ROMUL, SOILN, US model, Yasso) that are applicable for forest soils and that could be used for nationwide reporting to UNFCCC. In this paper the authors will describe how these models treat key factors affecting decomposition and how these models are applied and tested. This joint paper as well as other manuscripts resulting from presentations of the meeting will be submitted to *Silva Fennica* by August 15 to be considered as a special issue on methodological development of soil carbon monitoring in this journal.

Local organizers of the workshop were Raisa Mäkipää and Mikko Peltoniemi from the Finnish Forest Research Institute. Member of the Scientific advisory board were Dr. Pete Smith (University of Aberdeen, UK), Prof. Mats Olsson (SLU, Sweden), Dr. Esther Türing (Swiss Federal Research Institute WSL, Switzerland), Dr. Jari Liski (Finnish Environment Institute, Finland) and Dr. Raisa Mäkipää (Finnish Forest Research Institute).

## Description of scientific discussion of and discussions at the workshop

The objective of this workshop was to assess current methodological development of soil carbon monitoring methods applicable for large-scale inventories. Among other parties of the Climate Convention and signatory countries of the Kyoto Protocol, EU has commitments to report changes in the carbon stocks of forests, including the carbon stock of soils. As none of the current national or international soil survey networks is designed for carbon inventories, there is an urgent need for development of reliable and effective methods to monitor soil carbon. The workshop evaluated and discussed possibilities to apply existing, well-validated soil carbon models as well as current soil surveys, knowledge on the spatial variation of soil carbon and sound statistics to monitoring changes in soil carbon on regional scale.

Forests have been accounted for in the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol because of their importance for atmospheric carbon dioxide concentration. Participants of the workshop agreed that there is urgent need for development of reliable and feasible soil carbon inventories, since after the Kyoto Protocol countries have commitment to report changes in the carbon stocks of forest soils. The IPCC report on good practice guidance (2003) set general requirements for soil inventories, but monitoring have to be operationalized in various conditions of the signatory countries.

First session with a keynote presentation by prof. Mats Olsson (SLU, Sweden) was focused on national soil surveys and possibilities to improve their applicability for carbon inventories. Repeated sampling of soils would be clearly the most transparent method to prepare the estimates of changes in soil C. However, presently, only few countries (UK, Belgium, and Sweden) run soil surveys that are or may be able to provide nationwide estimates of soil C stock changes. Establishing such surveys in all countries seems unrealistic due to high costs and extensive effort needed to collect data in nationwide sampling. However, an example of the plans to establish such inventory in US was given in contributed presentation of this session. Repeated soil C measurements from limited number of sample plots are also needed and can be used for preliminary estimation of trends in soil C. An example of the repeated soil C measurements in the ICP sample plots in Bulgaria was presented in this session. In this workshop, availability of repeated C measurements of forest soil was discussed and their potential importance in model testing recognized.

In the second session workshop discussed on the state of the art soil models in estimation of decomposition and soil carbon budget. To be useful, the model-estimates must be reliable. Their reliability depends on, first, how realistically and comprehensively the models describe the processes and factors controlling the carbon balance and, second, how accurately the effects of the chosen processes and factors are quantified in the models. The first requirement calls for complex models whereas the second limits their usefulness as data available may be inadequate to determine the values of their numerous parameters. A keynote presentation by Dr. Jari Liski (Finnish Environment Institute) discussed what is an appropriate compromise between the complexity of a model and the possibility to determine its parameter values? A way to answer this question is to validate the output of the model, both the whole model and its parts, against various measurements. Contributed presentations of this session provided examples of various models that have been applied for large scale or smaller scale assessments of forest carbon budget and how the models have been tested and validated. The workshop agreed that many state of the art models can be applied for soil carbon assessment and selection of the model is highly dependent on availability of the input data.

Last session of the workshop discussed how models and soil surveys can/could be combined and what advanced can be achieved by model-based approaches in development of soil carbon monitoring programmes. In the keynote presentation by Dr. Stephen Ogle (Colorado State University, US) several steps for developing a robust model-based monitoring system were described and discussed, including 1) select/develop an appropriate model, 2) verify the adequacy of the model by comparing to measurement data, 3) identify sources of model input data such as soil surveys, land use and management activity records, and climatic data, 4) assess uncertainties, 5) implement the model, and 6) evaluate results with an independent set of measurements. Example from the model-based (Century model) monitoring system for US agricultural lands was given in this presentation and details of the development of such monitoring system were discussed in the workshop.

Second keynote presentation of this session by prof. Pete Smith showed how model-based methods can be applied to assess climate impacts on European forest soils. He presented the first assessment of future changes in European forest SOC stocks using a dedicated process-based soil organic carbon (SOC) model and state-of-the-art databases of driving variables. Whilst climate change will be a key driver of change in forest soil carbon, changes in forest age-class structure and land-use change were estimated to have greater effects on soil C budget in Europe.

Contributed presentations of the third session gave examples how model-based approaches can be used for forest C inventories, stratification of sampling and scenarios. The workshop agreed that state of the art models can already provide tools for regional and nation-wide forest carbon inventories. Further development of the models can improve their applicability (e.g. for organic soils on peatlands) and tests of model validity will improve their reliability.

In addition to three sessions, modeling party of the workshop was aiming to evaluate how suitable state of the art soil models are for estimation of regional soil carbon stock changes. Five soil carbon models, namely Century, ROMUL, RothC, SOILN, and Yasso, were presented by authors who have developed a model or who are heavily involved in applications where the model is used. The workshop was aiming to

- To determine the key processes and input data that are required for reliable predictions of soil carbon stock changes on a regional level
- To study how the state of the art models use existing data
- To discuss how the models should be further developed to improve applicability for large-scale carbon inventories.

Focus was on forest soils and regional/national estimates of soil carbon stock change. Presentations on soil models gave a sort description of model structure and parameterization as well as implicit and explicit assumptions of the model. Furthermore, validations, previous applications, and suggestions how to apply the model on regional level were described and discussed by these presentations.

Several models are already applicable for nation wide soil carbon assessments on upland soils, but further development is needed to provide methods for C assessment of peatland soils. The reliability of the existing models can be improved by testing validity of the models against measured changes in soil carbon stock. The workshop discussed availability of the data for testing and agreed that set of available repeated measurements of soil C stock will be reviewed to help model validation.

## Assessment of the results and impact of the event on the future direction of the field

National and international soil surveys are carried out in European countries, but none of them has been designed for reliable carbon inventory on forest land. Due to high costs of the regionally representative soil surveys and soil carbon monitoring, sampling efforts need to be effectively allocated (e.g. with model based stratification) within a monitoring programme and monitoring programmes need to be supported by modelling and development of new methodologies. Many countries have already selected either fully or partly model-based approach for nationwide reporting of changes of carbon in forest soils and it seems likely that the number of countries using model-based approaches will increase.

According to common understanding of this workshop, model-based methods can provide first estimates of the carbon stock changes of forest soils at national and European scale. In addition, model-based approaches help in verification and harmonization of the carbon assessments of different countries, since inventory can be repeated with different models. This workshop also showed that the scenarios of the soil carbon sequestration in current and changing climatic conditions with different management practices can be derived with currently existing models. In addition, efficiency of the soil sampling can be improved by stratification that is based on model predicted changes in the soil carbon stock.

This workshop offered important forum for interaction between modelers, soil scientists and designers of the soil surveys. Event facilitated intercomparisons of the soil C models and discussions on their applicability for nation wide inventories. International cooperation between developers of the models improves the consistency of the inventories and helps in focusing the further development of the models for the most uncertain parts of the inventory (e.g. peatland soils, uncertainty analysis of the model-based approaches). In addition to results of the workshop realized already during the meeting, the workshop is aiming to write a review paper on models applicable for nation-wide soil C assessments. Such a paper will help countries that have not yet established their soil monitoring system to find appropriate and cost efficient ways to operationalize their inventories.