# Carbon in forest soils: lessons from Arenosols

**Kestutis Armolaitis**

Lithuanian Forest Research Institute, Liepu str. 1, Girionys, LT-53101 Kaunas distr., Lithuania,
e-mail: dirvo@mi.lt

Arenosols occupy 25-30% of Lithuanian forest area that comprise more than 2000 thou. ha. Approximately 500-700 thou. ha of agricultural land with non-fertile soils (mainly Arenosols) are or will be abandoned and could be afforested.

This presentation explores some features that were recorded in Scots pine (*Pinus sylvestris* L.) stands or plantations growing on Arenosols. It is based on: (1) Lithuanian forest soils monitoring (*ICP Forest* program) data of 1992 and 1998, and (2) the data obtained in afforested former arable land.

According to the forest soil monitoring data total weight of the organic layers increase with increasing age in the 30-100-year-old Scots pine stands. However such increase for the carbon (C) was not found even in the upper 5 cm mineral layer of Arenosols. Besides, in 1998 when compare to 1992, the mean concentration of C decreased significantly in mineral topsoil (0-20 cm). Hypothetically this could be explained by leaching of C due to the excessive precipitation during vegetative period of 1998 that occasionally exceeded 30-80 mm per day. Consequently, the estimation of C sequestration should be focused not only on C storage in organic layers and mineral topsoil (root zone) but also on depth at least as deep as 100 cm. Such deep vertical distribution in soil profile of C was found in the 45-year-old Scots pine plantations on former cultivated Arenosols. However, there the highest carbon concentrations were detected in thin (0-2 cm) Ah-horizon that is under the development below organic O-horizon.

Key words: Arenosols, Scots pine, forest soil monitoring data, soil carbon, vertical distribution.

# Measurement and Modelling of Soil Carbon Stocks and Stock Changes in Irish Soils

Paul Leahy[1], **Kenneth A. Byrne[1]**, Ger Kiely[1] and Deirdre Fay[2]

[1]Centre for Hydrology, Micrometeorology and Climate Change, Department of Civil and Environmental Engineering, University College Cork, Cork, Ireland.
[2]Teagasc, Johnstown Castle, Co. Wexford, Ireland.

Abstract for poster presentation at the International Workshop on Development of Models and Forest Soil Surveys for Monitoring of Soil Carbon, April 5-8, 2006 at Koli, Finland.

The total amount of soil organic C (SOC) in Irish soils in 2000 has been estimated at 2021 Mt (Tomlinson, 2005). Peat accounts for 53% of this with mineral soils storing the remainder. There is a need to understand the magnitude and flows of SOC stocks in soils not only to constrain the terrestrial C budget but also to predict the C sequestration potential of soils under different land uses, management systems and changing climatic conditions.

A recently commenced project seeks to advance understanding of SOC in Irish soils. The project has the following objectives:

1. To carry out a literature review of past and current Irish (and international) research in relation to SOC turnover.
2. To measure soil carbon stocks to a depth of 50cm at 50 sites (within the 1300 sites of the ongoing EPA and Teagasc funded project “Towards a National Soils Database”) throughout Ireland and to use this data to develop a quantitative assessment of SOC stocks in Irish soils (by extrapolating data gained at the 50 sites to the 1300 sites). In addition a further 10 peatland sites will similarly be assessed.
3. To measure a range of key soil properties at 10 sites to a depth of 0.5m (bulk density, sand/silt/clay fractions, total SOC and slow, active and passive SOC fractions).
4. To carry out an intensive soil sampling campaign at one site in order to test the detectability of soil carbon stock changes using conventional soil sampling techniques.
5. To integrate SOC and other soils data into SOM models (e.g. CENTURY, RothC, PaSim, DnDc). To determine the most suitable of these models for further development at the local, regional and national scale.
6. To analyse the finding in the context of UNFCCC and Kyoto Protocol.

This poster will describe the project and discuss the site selection procedure.

# Century model IN Soil organic carbon balance and $CO_2$ emission from agricultural Italian land

**Di Tizio A.**, Grego S.

Department of Agrobiology and Agrochemistry, University of Tuscia, Via S.Camillo de Lellis 01100 Viterbo, Italy.
E-mail: ditizio@unitus.it

**Introduction.** 46-49% Italian emission of greenhouse gas (GHG) ($N_2O$, $CH_4$) originates from agricultural practices; 17% of this emission come from soil organic matter degradation. Agricultural practices also affect soil organic carbon (SOC) stock and consequently soil $CO_2$ emission. Italy, ratifying Kyoto protocol, agreed to reduce 6.5% of GHG emission at 2012, compared with 1990 emission values. Italian agricultural surface in ten years diminished from 15 x $10^6$ ha (1990) to 13.2 x $10^6$ ha (2000); moreover, 2 millions of hectares were transformed from conventional to organic management. In our study the SOC balance and $CO_2$ emission from agricultural Italian lands in the years 1990 and 2000 were investigated using CENTURY ecosystem model v.5. The objectives of this work were to assess agricultural Italian soils contribution to atmospheric $CO_2$ enrichment and to estimate if the agricultural system can utilized to acquire carbon "credits", according to Kyoto provisions.

**Material and methods.** The study consisted of two temporal phases: 1) data base creation containing climatic information, management and agricultural characteristics of soils located in North, Center and South Italy, which are strongly affecting SOC; 2) data base use as input to run CENTURY model version v.5. SOC annual balance and $CO_2$ emission (reported for province and in tons/ha), obtained from CENTURY, were compared with a $CO_2$ emission inventory from IPCC (Intergovernmental Panel of Climate Change) published in 2004 by APAT (Italian Environment and Territory Protection Agency).

**Results and discussion.** The results, obtained by 40 simulations, showed significant higher values of $CO_2$ emission in agricultural soils in the South then Centre and North Italy in the year 2000 (1.87, 0.66 and 1.26 tons/ha/year, respectively); emission values of organic and conventional management were not significantly different. However, SOC annual balance decreased significantly in the three geographic areas (-10.5% South, -1.3% Center, and -2.7% North Italy) and for management (-4.9% conventional and -0.6% organic). A comparison of CENTURY simulation and $CO_2$ emission values from IPCC in three provinces of Center and South Italy showed a overestimate of CENTURY of 20%. Our results exhibit a general trend of SOC decline, while organic management seem to be a conservative agricultural system.

Acknowledgments: The work has been supported by CARBIUS Project.

# Measuring soil carbon changes at forest sites – experiences from a repeated sampling at a boreal site

**Elli Haapamäki** & Jari Liski

Finnish Environment Institute, P.O. Box 140, FIN-00251 Helsinki, Finland, *Fax: +358 9 4030 0390,
Tel: +359 40 587 1178, E-mail: elli.haapamaki@ymparisto.fi

There is a lack of the studies in which changes in soil carbon stocks have been measured because measuring these changes is laborious. A large number of samples are needed to distinguish these small temporal changes from the large spatial variation of C density. However, these measurements would be needed, on the one hand, to plan strategies to monitor changes in soil carbon stocks, on the other hand, to validate results of simulation models used to estimate these changes. The objective of this study was to measure the changes in the amount of soil C at a Scots pine (Pinus sylvestris) site in southern Finland over a 12 year period. In addition, based on the results we estimated the number of soil samples needed to determine these changes.

The density of soil organic carbon (kg/$m^2$) was measured in a 6 x 8 m area in 1993 and again 12 years later by taking 125 soil cores in both occasions. Between the samplings in 1995, the 100-year-old pine stand was final cut and only some 50 trees per hectare were left standing as seedtrees. The soil was prepared to help natural regeneration.

The C density decreased in the organic F/H layer by 0.6 kg/$m^2$ (from 1.8 to 1.2 kg/$m^2$) but increased in the topmost 0-10 cm mineral soil layer by 0.2 kg/$m^2$ (from 1.4 to 1.6 kg/$m^2$). In the 10-20 cm mineral soil layer the density decreased by 0.06 kg/$m^2$ (from 0.80 to 0.74 kg/$m^2$) and in the 20-40 cm layer by 0.05 kg/$m^2$ (from 0.43 to 0.38 kg/$m^2$). All these changes were statistically significant. Based on our measurements, we estimated how large the changes could have been to still argue that the C density had not changed, and, on the other hand, how small the changes could have been to argue that the C density had changed – dissimilarity and similarity are not statistically the same thing. The results and methods of this study are useful for planning measurements of soil carbon changes at forest sites.

# The methodology used in greenhouse gas inventory of Finnish forest soils in year 2005

**Timo Kareinen***, Risto Sievänen, Hannu Ilvesniemi, Timo Penttilä, Aleksi Lehtonen, Mikko Peltoniemi

Finnish Forest Research Institute, PO Box 18, FI-01301 Vantaa, Finland, * Timo.Kareinen@metla.fi

Abstract

The greenhouse gas inventory of Finnish forest soils is part of Finnish national GHG inventory for EU, belonging to the LULUCF (Land Use, Land Use Change and Forest) sector. The carbon stock changes of the LULUCF sector are one of the key categories in Finnish inventory and the methodology used is consistent with IPCC Good Practice Guidance Tier 2 analysis. The forest soils inventory concerned stock changes of dead organic matter, litter and soil organic matter, and the associated GHG emissions and removals.

The calculation routine used in GHG inventory of forest soils in year 2005 (covering years 1990-2004) included estimation of annual litter production, which was added to the litter stock, and then calculation of the decomposition of all the organic matter stocks. The change in organic matter stocks caused by land use changes could not yet be estimated. The inventory was made separately for mineral and organic soils. Only drained peatlands were considered as organic soils, undrained peatlands were assumed to be in stable state and not affecting the GHG balance. Stock changes of litter, SOM and dead wood pools were estimated with Yasso model, except in the case of peat decomposition, which was assessed using site specific emission coefficients and estimates of the annual below ground litter inputs.

Annual litter production consisted of litter production from living biomass (trees, ground vegetation), natural mortality of trees and harvesting residues. In mineral soils the litter production of the ground vegetation was not yet included, since reliable estimates were lacking. The annual litter production was estimated from forest data measured in National Forest Inventories (NFIs) and from reports of roundwood purchasers and Metsähallitus.

The parameterisation of Yasso included assessment of the decomposing properties of different biomass compartments and also the temperature effect on decomposition rate in south and north. Initial state of the model was estimated with a long initiating period with reasonable and smoothly increasing litter input. In mineral soils the inventory simulation started from 1940 with actual estimated litter input, in drained peatlands the inventory simulation started from 1990.

GHG balances were reported as 5 years moving averages, emphasis being in the long-term trends of changes.

# Litter decomposition in a Mediterranean woodland: a link between measurements and modelling approaches

**D. Piermatteo[1]**, F. Miglietta[2], S. Ogle[3], M.F. Cotrufo[1]

[1]Environmental Science Department Second University of Naples, Caserta, Italy
[2]CNR IBIMET, Firenze, Italy
[3]NREL, Colorado State University, Fort Collins, USA

Abstract: Leaf litter decay is conventionally studied by the litter bag method and models of litter decay rates are built to best fit the mass loss data from litter bag. However, bags, by preventing loss to the mineral soil due to fragmentation, may bias the process.

Litter decomposition is included in SOM models with a large uncertainty on how to describe litter quality and its controls on C transfers to SOM, as well as, its interactions and feedbacks with the physical and biological environments. Potential decomposition rates of similar litter fractions vary considerably between different models and most existing models have been developed to describe a set of different ecosystems but mostly in the Temperate zone. The lack of data and long-term experiments makes it difficult to estimate how well these models simulate Mediterranean ecosystems. The Century model underestimates C in litter layer and thus more information is required on how to apply it to forest soils with a well-developed litter layer. Objective of this research project is to link a litter decay model, as Century, and measurements using different experimental and modelling approaches. In particular we want to quantify input C to soil from litter layer in a Mediterranean woodland under different precipitation patterns, measuring litter dynamics with a different method without the artefact of litter bag and finding model who best fit experimental results to predict the mean residence time of C at a long-term scale and in different scenarios. We applied the Century model to an *Arbutus unedo* coppiced woodland, in central Italy, where since a year a large scale through fall manipulation experiment is ongoing, in the framework of the MIND project. A year of measured litter mass loss and quality dynamics will be illustrated. We used all the results to evaluate Century model and implement it in Mediterranean climate change. We transferred Century soil carbon sub-model in Simile, a useful and visual modelling environment in which to test such models. Simulation data will be presented.

# How can we improve the efficiency of soil sampling for monitoring soil carbon at a European scale - Theoretical considerations

**Schrumpf, M.***, Schumacher, J.*, Schöning I.* & Schulze, E.D.*

* Max-Planck-Institute for Biogeochemistry, 07745 Jena, Germany

Soil carbon concentrations and stocks exhibit a huge variability at all spatial scales ranging from a few cm to the continental level, making the detection of changes in field measurements a real challenge. Three European-wide soil surveys were used to create soil carbon maps, which aimed to serve as a basis for soil carbon monitoring: the Soil Geographical Database of Europe, the Geochemical Baseline Mapping Program and the ICP Forest Level I monitoring. But soil sampling in these surveys usually took several years to be completed, so that there is no specific baseline year for monitoring and no resampling was accomplished yet.

Most soil monitoring programs use a regular grid design for soil sampling but that goes along with a huge sampling effort. In order to reduce the sample size, stratification according to parameters that lead to a reduced variance within the strata as compared to the total area would be useful. Parameters which are frequently used for up-scaling in soil carbon maps and to evaluate country wide estimates in C-stocks include soil types, land use and climate. The suitability of those factors for stratification in a new sampling approach should be tested using existing European soil databases.

But the question arises, whether a stratification that aims to increase the accuracy of the existing carbon stocks is also suitable for the detection of changes. From a statistical point of view a paired sampling design, in which exactly the same places are observed regularly, is most efficient for the detection of changes. In that case, the differences between the pairs would be analysed thus reducing the effect of large-scale variance on the results. To increase the detectability of changes, the variance of changes has to be reduced. Thus, stratification should be made according to parameters that influence the magnitude and direction of changes. But the existing database for measured changes is scarce. Therefore, we would recommend the usage of soil models in combination with available databases to identify the influence of soil types, land-use systems or climatic regions on changes and their variability under different future scenarios. Analysis of the minimum detectable differences of the generated strata should be made to determine the required sample sizes and test the practicability of such an approach.

# Integrating Models and Inventories – Modelling Theory Support on Coupling and Validation

**Thomas Wutzler**

Max Planck Institute for Biogeochemistry, Hans-Knöll-Straße 10, 07745 Jena, Tel +49 3641 576104,
email: thomas.wutzler@bgc-jena.mpg.de

Results of a simulation often do not agree with measurements. The error originates either from wrong assumptions of the model, or from incorrect execution of the model. Theory of modelling and simulation (M&S) distinguishes between the model itself and the simulator to execute the model. The correctness of software to execute this model can be verified for broad classes of models. The error can be ultimately bounded within a given range. A precondition for using this is, to specify the model according to a given modelling paradigm. We shortly introduce three of the most common modelling paradigms. Next, we shortly explain the simulation of a model that is specified by differential equations. Finally, we demonstrate how errors can occur when using unsophisticated simulation algorithms. We give an example with the soil carbon model YASSO.

In a second part we elaborate on describing (and implementing) models as a hierarchy of sub models. Advantages are the more general usage of submodels in yet unknown applications, an easier verification and validation of simulators and models, and less effort of developing and testing new models and simulators. We introduce the basic coupling approach of the DEVS-bus. Finally, we demonstrate the usage by specifying the soil carbon model YASSO as a coupled DEVS-submodel and extend it to mixed stands.

We give an outlook how the mixed stands soil model can be coupled to the empirical mixed stand forest growth simulator TreeGrOSS. The forest coupled model will be integrated to a GIS in order apply it with inventory data on a landscape basis.

# Measuring Roth-C pools by DRIFT-spectroscopy

**Michael Zimmermann**[1], Jens Leifeld[1], Michael W. I. Schmidt[2] & Jürg Fuhrer[1]

[1]Agroscope FAL Reckenholz, Swiss Federal Research Station for Agroecology and Agriculture, Reckenholzstrasse 191, CH-8046 Zurich, Switzerland
[2]Geographisches Institut der Universität Zürich, CH-8057 Zurich, Switzerland
e-mail: michael.zimmermann@fal.admin.ch

To estimate the potential of soils to sequester additional atmospheric $CO_2$, better understanding of the response of soil organic carbon (SOC) in fractions of different turnover rates to changes in environment and management is necessary. Changes in the amount and distribution of SOC can be estimated by means of soil organic matter (SOM) turnover models, which typically consist of 2 to 5 SOC pools. We fractionated 123 topsoils from agricultural sites (arable land, grassland and alpine pasture) across Switzerland to isolated two sensitive (particulate organic matter and dissolved organic carbon), two slow (carbon associated to clay and silt or stabilised in aggregates) and a passive (oxidation resistant carbon) SOM fraction. These SOC fractions were then compared with Roth-C modelled pools for the corresponding soils in equilibrium. Spearman's correlation coefficients ($R$) between SOC in measured fractions and modelled pools varied between 0.82 for decomposable plant materials (DPM), 0.76 for resistant plant materials (RPM), 0.99 for humified organic matter (HUM) and biomass (BIO), and 0.73 for inert organic matter (IOM). We developed a method to predict SOC contents of fractions by a much faster way as fractionation, i.e. by diffuse reflectance infra-red spectroscopy (DRIFT). DRIFT spectra of bulk soil samples were calibrated against measured SOC values of fractions by means of partial least squares (PLS) statistics. PLS separate spectra into few latent variables representing the most relevant mineral and organic compounds of the given calibration data. As result, we receive statistical prediction models to estimate SOC values of different fractions from DRIFT spectra with unknown values. In a first step, we determined prediction models to estimate the SOC contents in the sensitive, the intermediate and the resistant SOC fractions. Calibrations were computed with 100 bulk soil spectra and validated against 10 independent spectra not used in calibration. Pearson's correlation coefficients (r) between measured and predicted SOC fractions range from 0.89 for resistant, 0.91 for sensitive and 0.97 for intermediate SOC fractions. We conclude that DRIFT-spectra, in combination with PLS statistics, enable us to estimate RothC pools, which can be used to initialise RothC at any point in the landscape even when historical data are lacking.