Components of forest soil CO_2 efflux as estimated from $\Delta^{14}C$ values of SOM

M. Rodeghiero (1), R. Hakkenberg (2), G. Churkina (3), C. Martinez (1), T. Scholten (4), A. Cescatti (5)

(1) Fondazione Edmund Mach, Research and Innovation Centre, 38010 S. Michele All'Adige, Trento, Italy

(2) Max-Planck-Institute for Biogeochemistry, Hans-Knöll-Strasse 10, 07745, Jena, Germany

(3) Institute of Geography, Humboldt University of Berlin, Rudower Chaussee 16, 12489 Berlin, Germany.

(4) University of Tübingen, Institute of Geography, Rümelinstrasse 19-23, 72070 Tübingen.

(5) European Commission - DG Joint Research Centre, Inst. for Environ. and Sust., Climate Change Unit, Ispra, Italy

contact: mirco.rodeghiero@iasma.it

Introduction

Partitioning of soil CO_2 efflux into autotrophic (SOM-derived) and heterotrophic (root-derived) respiration is a research priority to improve our ability to predict the net response of soil carbon stores to climate change. Using the $\Delta^{14}C$ value of a SOM pool measured at a point in time, a turnover time of the SOM pool can be estimated using a simple model in conjunction with a record of atmospheric $\Delta^{14}CO_2$ concentrations. Following the conversion of $\Delta^{14}C$ values to turnover times, soil CO_2 efflux from SOM pools can be calculated as the ratio of their carbon stocks and turnover times.

Methods

Site selection and soil respiration measurements

The study was performed in northern Italy in eleven forest sites located along an elevation gradient from 220 to 1740 meters above sea level (a.s.l.). Seven sites were dominated by an evergreen tree species and the remaining four by a deciduous species (see Table 1). Soil CO_2 efflux was investigated in a previous study by Rodeghiero and Cescatti (2005), who determined total annual soil CO_2 efflux at each site using chamber based soil respiration measurements.

SOM Turnover Times:

Turnover times for litter, light and heavy SOM fractions were calculated, based on their $\Delta^{14}C$ values, by applying a modeling approach (Hakkenberg et al., 2008), which assumes that (1) annual carbon inputs to the SOM pool are constant and (2) SOM pools are at steady state. The change in $^{14}C/^{12}C$ isotope ratio of a SOM pool (RSOM) over time can then be described as (following Gaudinski et al., 2000; Bird & Torn, 2006): $RSOM(t) = k \times Ratm(t) + RSOM(t-1) \times (1 - k - \lambda)$ where k = SOM decomposition rate (yr^{-1}); λ=^{14}C radioactive decay constant (0.00012 yr^{-1}); Ratm = $^{14}C/^{12}C$ isotope ratios of atmospheric CO_2 calculated from atmospheric $\Delta^{14}C$ values; t = time (yr) for which calculation is being performed.

Table 1 - Some characteristics of the investigated sites

Site (abbreviation)	Elevation (m a.s.l.)	Forest type	Dominant species	Litterfall (gC/m2/yr)
Casteller (CaH)	220	Hop hornbeam	*Ostrya carpinifolia*	214 (26)
Toblino (ToO)	250	Holm oak	*Quercus ilex*	515 (72)
Mattarello (MaP)	420	Austrian pine	*Pinus nigra*	328 (24)
Lagolo P (LaP)	760	Scots pine	*Pinus sylvestris*	188 (6)
Lagolo B (LaB)	970	European beech	*Fagus sylvatica*	233 (25)
Brigolina B (BrB)	1020	European beech	*Fagus sylvatica*	257 (31)
Brigolina S (BrS)	1020	Norway spruce	*Picea abies*	275 (21)
Vaneze (VaS)	1150	Norway spruce	*Picea abies*	147 (17)
Lavarone (LaF)	1370	Silver fir	*Abies alba*	254 (12)
Bondone (BoB)	1470	European beech	*Fagus sylvatica*	177 (6)
Renon (ReS)	1740	Norway spruce	*Picea abies*	115 (12)

References

*Hakkenberg R, Churkina G, Rodeghiero M, Borner A, Steinhof A and Cescatti A 2008 Temperature sensitivity of the turnover times of soil organic matter in forests. Ecological Applications 18, 119-131.

*Rodeghiero M and Cescatti A 2005 Main determinants of forest soil respiration along an elevation/temperature gradient in the Italian Alps. Global Change Biology 11, 1024-1041.

*Smith M L, Ollinger S V, Martin M E, Aber J D, Hallett R A and Goodale C L 2002 Direct estimation of aboveground forest productivity through hyperspectral remote sensing of canopy nitrogen. Ecological Applications 12, 1286-1302.

*Vitousek P M, Hattenschwiler S, Olander L and Allison S 2002 Nitrogen and nature. Ambio 31, 97-101.

Results

The total $\Delta^{14}C$-based decomposition fluxes of the sites ranged from 164 to 447 g C/m²/yr, with by far the largest contribution (on average 81%) from the litter layers (Figure 1).

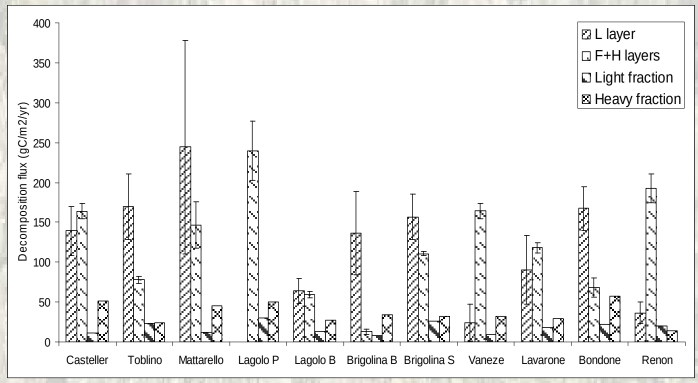

Fig. 1 – Estimated annual carbon fluxes released by the decomposition of the three SOM fractions.

The fraction of total soil CO_2 efflux remaining after subtracting the total SOM-derived CO_2 flux from the chamber measured flux was presumed to be respiration derived from recently fixed carbon (Figure 2). The root respiration from recently fixed carbon was obtained as the difference between the recently fixed carbon total CO_2 efflux and the estimated respiration of the litter within the first year after litterfall . This resulted in an average root-derived respiration of ~ 50% of the total soil CO_2 efflux.

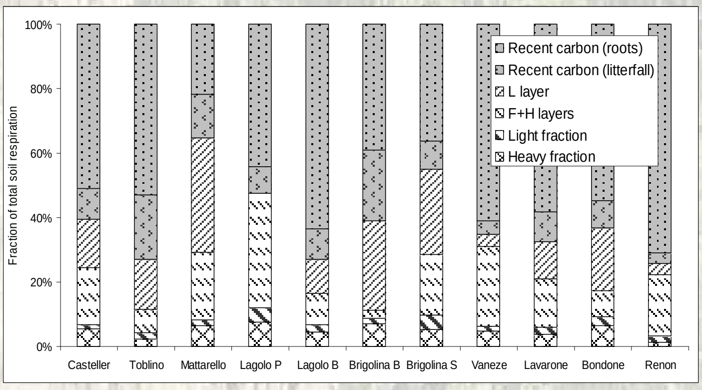

Fig. 2 – Partitioning of total annual soil CO_2 efflux into SOM-derived components and components derived from recently fixed carbon.

Conclusions

The decomposition flux derived from the litter layers was by far the largest fraction of the total decomposition flux (on average 81%).

The $\Delta^{14}C$-based decomposition fluxes of the different SOM fractions as estimated here, suggested that most of the annual carbon inputs to the SOM pool took place aboveground and to a much smaller degree in the mineral soil.

A very large fraction of the total soil CO_2 efflux (~ 90%) resulted from root respiration and decomposition of fresh organic matter ($\Delta^{14}C$-based litter-derived respiration plus the respiration from recently fixed carbon).

Acknowledegements

We thank Annett Borner, Gerd Gleixner, Martina Mund, Markus Reichstein and Susan Trumbore for discussion of results. This study received funding from the EU-CarboDATA project (contract number EVK2CT-1999-00044) and from the Province of Trento, Italy (grant REM DL1060).