CHANGING SOURCES OF SOIL RESPIRATION WITH TIME SINCE FIRE IN A BOREAL FOREST

C.I. Czimczik, M.S. Carbone, G.C. Winston, and S.E. Trumbore

Department of Earth System Science, University of California Irvine, 2103 Croul Hall, Irvine, CA 92697-3100; czimczik@uci.edu, mcarbone@uci.edu, gwinston@uci.edu, setrumbo@uci.edu

ABSTRACT
Stand-replacing crown fires in boreal spruce forests initiate a vegetation succession from forbs to deciduous trees to coniferous trees. Soils are warmest during the first decades and cool throughout the succession as shading by trees and cover with bryophytes and plant litter increase. It was postulated that the initially warmer soil temperatures enhance decomposition of soil organic matter (SOM) by microorganisms, and that decomposition would release similar amounts of CO_2 as combustion during fire [*Auclair and Carter*, 1993].

We tested this hypothesis by studying CO_2 effluxes from the soil surface along a fire chronosequence in Canada. We used the radiocarbon content of CO_2 ($\Delta^{14}C$) to partition the flux from the soil surface ('soil respiration') into CO_2 evolving from the respiration of tree roots, their associated microorganisms, and mosses (collectively called 'autotrophic respiration') and from microorganisms decomposing older SOM ('heterotrophic respiration').

We assumed that decomposition losses would be largest from the organic layers, since most carbon in upland boreal forests is present on the mineral soil surface. However, the organic layers can be partially removed by fires and expose carbon in the mineral soil to higher temperatures. Therefore, we also quantified carbon losses from the mineral soils.

METHODS
We measured soil respiration of six former black spruce forests stands that had burned 0 to 150 years ago. During a warmer (2003) and a cooler (2004) growing season, we sampled CO_2 from soil respiration with chambers, from autotrophic respiration by incubating roots and mosses, and from heterotrophic respiration by incubating organic layers. The contributions of the two respiration sources to soil respiration were calculated with an isotope mass balance based on the natural abundance of ^{14}C in respired CO_2 ($\Delta^{14}C$). $\Delta^{14}C$ of CO_2 was measured with accelerator mass spectrometry.

To quantify losses of carbon from mineral soils, we measured CO_2 concentrations, $\Delta^{14}C$ of CO_2, temperature and moisture at various depths.

RESULTS AND DISCUSSION
Soil respiration was lowest in May and highest in July as was plant productivity (Fig. 1). Seasonal and interannual variations were largest in young stands lacking a soil insulating moss layer [*Czimczik et al.*, Submitted].

$\Delta^{14}C$ of root-respired CO_2 from deciduous and young coniferous trees, forbs, and mosses was similar to that of recent photosynthetic products. It dropped from 70‰ in 2003 to 64‰ in 2004. Black spruce roots from trees >40 years respired CO_2 up to 6 years older, especially in 2003.

$\Delta^{14}C$ of decomposition-derived CO_2 from organic layers was >120‰, and did not differ seasonally or interannually. It was higher in young stands where more litter accumulated during the peak of $^{14}CO_2$ in the atmosphere in the 1960s.

Mineral soil CO_2 concentrations increased and its $\Delta^{14}C$ became more positive as soils warmed during the growing season.

We found no post-fire peak of soil respiration rates from the decomposition of fire residues (Fig. 1). Respiration rates were highest 40 years since fire (145 mg C m^{-2} hr^{-1}) as was plant productivity. Until 40 years since fire, autotrophic respiration (>80%) dominated. After 70 years when black spruce and mosses gained dominance, the autotrophic proportion decreased to 50%.

CO_2 in mineral soils originated primarily from autotrophic respiration. CO_2 production from decomposition seemed to be higher in the warmer year 2003, while decomposition of organic matter in the organic layers (and maybe also autotrophic respiration) was suppressed by moisture limitations. In the colder year 2004, the $\Delta^{14}C$ signal from decomposition of old carbon in the mineral sol was masked by high fluxes of CO_2 from autotrophic respiration and decomposition in the organic layers. We concluded that under higher fire frequencies leading to warmer soils, the loss of mineral soil carbon will be slow.

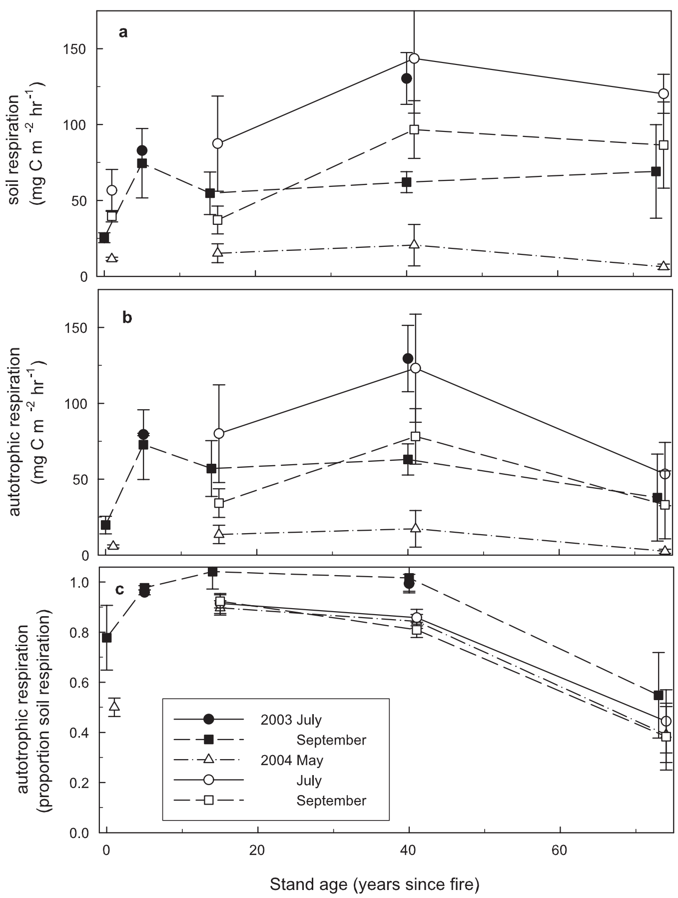

Fig. 1 (a) Soil respiration at the soil surface, (b) autotrophic respiration (CO_2 respired by roots, mosses, and microorganisms feeding on plant exudates), and (c) autotrophic respiration as a fraction of soil respiration with time since fire during a warmer (2003) and a cooler (2004) growing season.

REFERENCES

Auclair, A. N. D. and T. B. Carter (1993), Forest wildfires as a recent source of CO_2 at northern latitudes, *Can. J. For. Res. 23*,1528-1536.

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