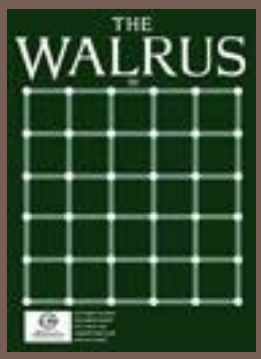

SOIL CARBON QUANTITY AND QUALITY TWENTY YEARS AFTER ESTABLISHMENT OF TEMPERATE GREAT LAKES CONIFER PLANTATIONS

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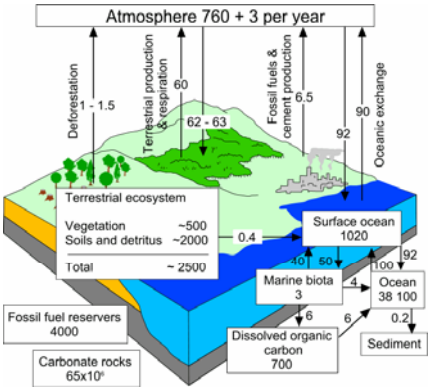
Northern forest ecosystems

Global carbon cycle

- 2100 Gt of carbon in terrestrial ecosystems
- 2/3 of this in soil, the majority in forest and wetland soils
- Uncertainty about the long-term stability of pools under climate change
- Potential of soils to sequester carbon?



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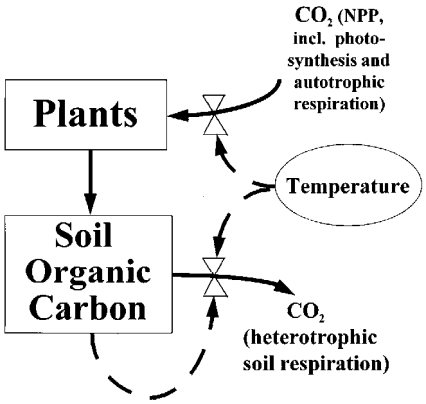
The role of plantations and plantation soils?

- Afforestation or reforestation has not yet played a significant role in Kyoto (via CDM)
- Intensification of silviculture as part of land use zoning (TRIAD)
- Intensification to produce biomass for bioenergy

worldbank.org

Silviculture and soil C

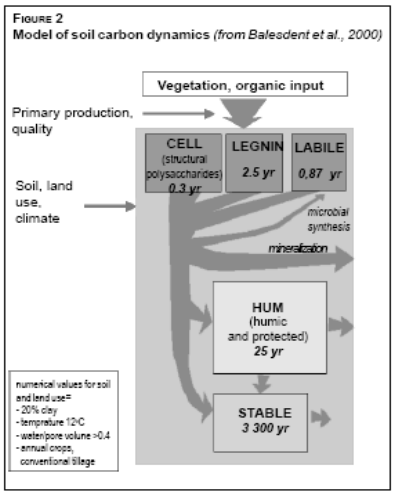
- Species changes (litter)
- Understory vegetation modified (functional grps)
- Soil microclimate: changes in temperature and moisture
- Changes in soil microbial community structure (functional grps)

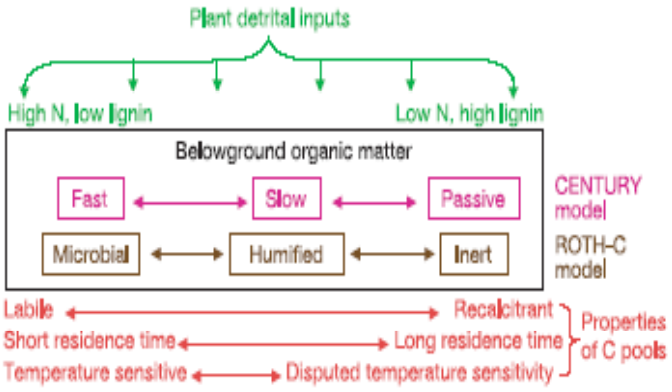


(Kirschbaum 2000)

Where is the soil carbon?

- Most of the carbon entering the soil is labile
- Only about 1% of the carbon that enters the soil accumulates in the most stable fraction
- Different pools have different resident times in the soil (e.g. microbial biomass, cellulose, lignin)





Davidson and Janssens 2006 (Nature)

Silvicultural treatments and soil C

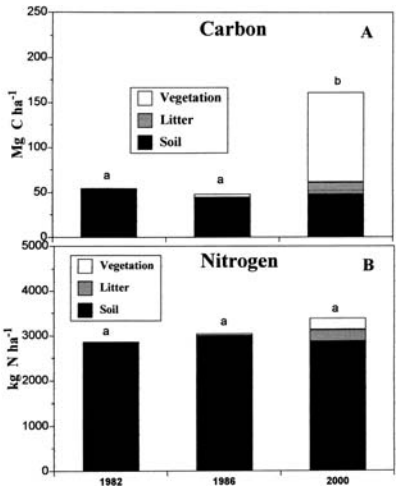
- Plantations require site preparation, tending, perhaps fertilization, thinning etc.
- …site preparation always stimulates soil microbial activity; the intended effect of activating the nutrient cycle is adverse to C sequestration (Jandl et al. 2007)
- … thinning increases stand stability at the expense of the C pool size (Jandl); minimal influence of thinning on soil C (Tarpey et al)

Silvicultural treatments and soil C

- N fertilization affects above-ground biomass; effect on soil C depends on interaction of litter production and carbon use efficiency of microbes; N fertilization leads to emission of GHG from soils
- Species effects on C storage on stable soil pools controversial and so far insufficiently proven (Jandl et al. 2007)

C and N in a loblolly pine plantation ecosystem: 18 yr

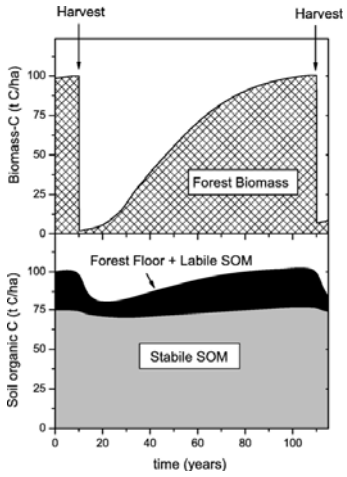
(Johnson et al. 2003)



Changes in SOM after harvest

- Soil respiration increases after harvest – assumption here is that labile C is lost more readily

- Several studies have suggested or hypothesized that labile C is more subject to changes due to intensive silviculture (Khanna et al. 2001)



Jandl et al. 2007

Study objectives

- Temperate Great Lakes plantation with native pine and spruce

- Evaluate soil carbon stocks twenty years following intensive silvicultural treatments (estimate fine root input)

- Evaluate changes in carbon quality: labile, intermediate and recalcitrant carbon in response to silvicultural treatments

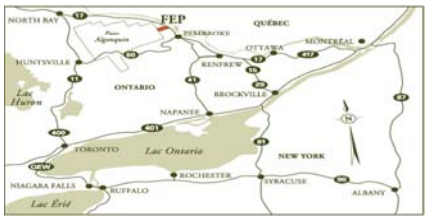
Plantation in 1986, evaluation 1989, 1996, 2006

Articles:

- Brand, D.G. and Janas (1988) CJFR
- Ohtonen et al. (1992) Ecol Appl
- Munson et al. (1993) SSSAJ
- Périé et Munson (2000) SSSAJ
- Maillard et al. Submitted.

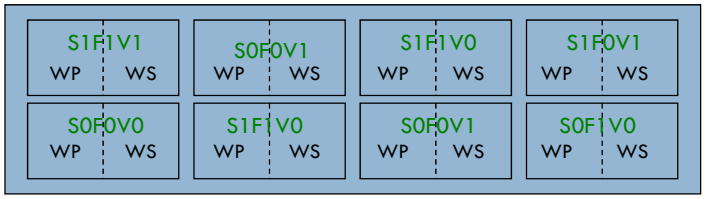
Petawawa Research Forest, Chalk River, Ontario

Forest before harvest / silvicultural treatments



- Great Lakes mixedwood:
  - *Populus tremuloides*
  - *Betula papyrifera*
  - *Picea glauca*
  - *Betula alleghaniensis*
  - *Tilia americana*
  - *Pinus strobus*
  - *Abies balsamifera*
- Soils: Orthic Humoferric Podzol = Typic Haplorthod
  - Well-drained sandy loam

Two species, *Pinus strobus* et *Picea glauca*



Intensive silvicultural treatments: EXTREME

Control

(S1) = Blading

Three treatments: Blading (S1)
Fertilization (F1), Herbicide (V1)

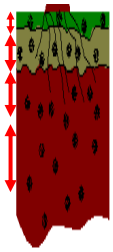
Plantations at 10 years

S0F1V1

S1F0V1

Methods

- Litter
- FH horizon
- Mineral (0-15 cm)
- Mineral (15-40 cm)

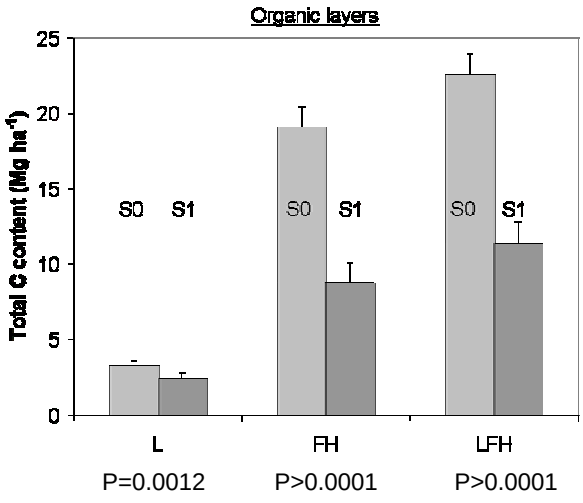


- 14 cores per plot
- 2 cores for bulk density
- Carbon analyses: LECO
- Ingrowth root cores during one year (roots < 2mm; Gleeson and Good)

Methods

- Long term incubation (up to 8 mo) and respiration measures with micro-GC (method of EA Paul modified by Paré et al 2006)
- Labile C: cumulative C mineralized at day 189 (NLIN curve fitting)
- Recalcitrant C_R: acid hydrolysis
- Slow C: Ctot – C_{189}-C_R

Blading effects on the organic layer



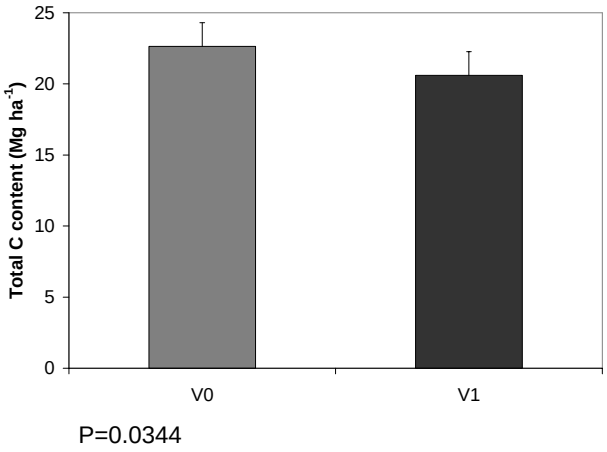
Herbicide reduces total carbon in surface mineral soil (0-15 cm)

- Reduced root input (Shan et al.)

- Lower %cover of herbaceous and shrubs (V1)

- Conifers accumulate less C in surface mineral vs. deciduous (Jandl)

- Also observed recently by Sartori et al.

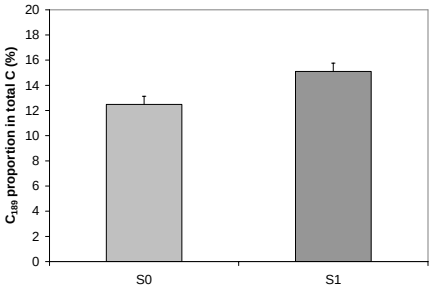


Summary of results on C stocks

- On bladed plots 11.4 t C/ha accumulated in a new organic layer (1.2 cm less than the control plot)
- Compared to non-bladed plots, C content in L and FH layers were 26% and 54% lower in bladed plots
- Herbicide reduced total C in surface mineral soil by 9%
- Fertilization reduced the negative impact of blading (interaction p=0.035)
- Scarification tended to decrease C content in 15-40 cm depth layer (p=0.056) (Stimulus effect: 'priming'?)

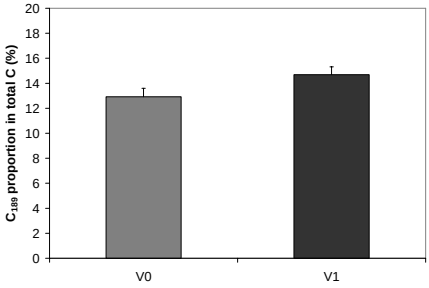
Labile C increases in response to blading and herbicide use (as proportion of total C)

p=0.0058

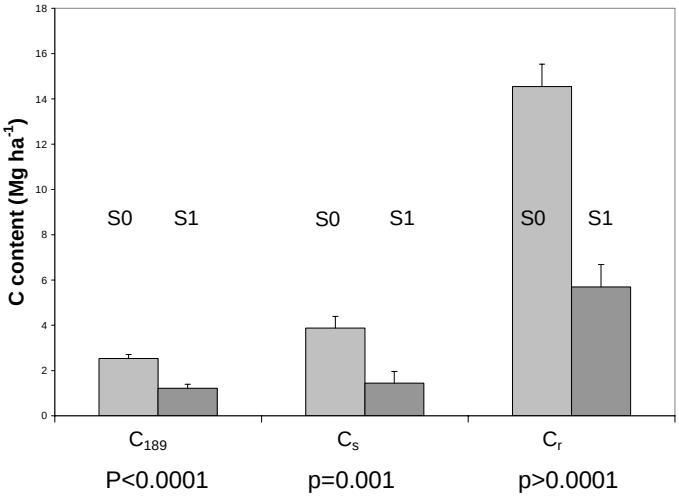


There is less labile carbon, but the proportion of labile carbon of total increases

p=0.0504

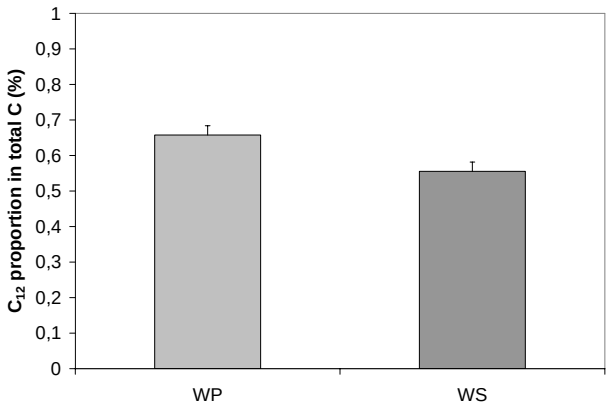


Blade scarification and soil C pools



P<0.0001 p=0.001 p>0.0001

Tree species effect on the proportion of cumulative mineralized C at day 12 (labile)

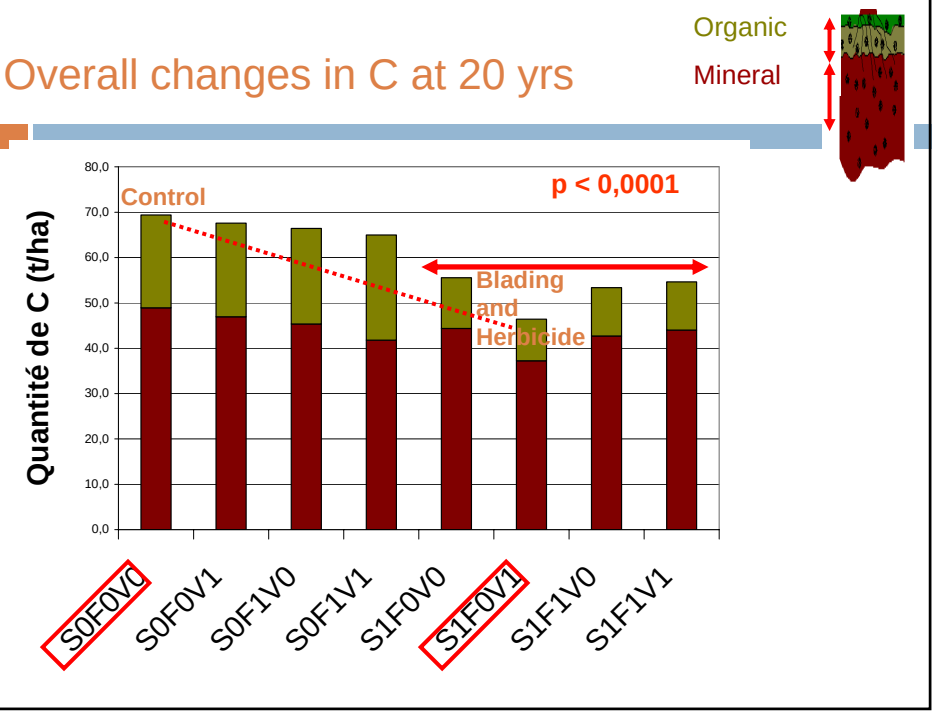


Cumulative mineralized C at day 12 (C_{12}) (p=0.0018) in the total C of the surface mineral layer (0-15 cm)

Fine root regeneration in the FH and mineral horizons (mg/cm^3/yr)

Species	Fine root density in FH	Mineral (0-15 cm)
White pine	1.1 (0.3) a	0.3 (0.1)
White spruce	1.9 (0.8) b	0.3 (0.2)

Overall changes in C at 20 yrs



FINAL Final Message

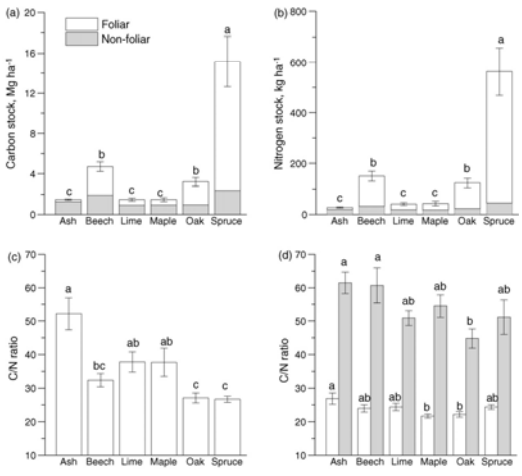
- After 20 years, soil carbon stocks were reduced by intensive silvicultural treatments (blading, herbicides)
- Soil carbon at deeper depths tended to decrease
- Some species effects apparent after 20 years
- A greater proportion of labile C in the total carbon content was observed following intensive treatments
- More stable pools of C were affected by blading

QUESTIONS? THANKYOU

- Natural Sciences and Engineering Research Council of Canada
- Abitibi-Bowater (fellowship E Maillard)
- Summer students: Eduard Mauri-Ortuno, Annik Grenier, Olivier Roy

Species effect on soil carbon, nitrogen

- Common garden design
- 30 years
- Higher C and N stocks under spruce
- Species with lower C and N in ffloor had higher C and N in mineral soil



Vesterdal et al. 2008