



## Canadian Carbon Program and Fluxnet Research Sites Canadian Forest Service Ground-Level Research

### INTRODUCTION

Canada's forests play an important role in the global carbon cycle. Forests exchange carbon dioxide with the atmosphere through the processes of photosynthesis, respiration, and decomposition. The boreal forest, which constitutes close to 80% of Canada's forest area, is thought to be an important carbon sink for the atmosphere, as carbon is taken up by growing trees. Natural Resources Canada, Canadian Forest Service (NRCan, CFS) has tracked carbon stocks and fluxes in forest ecosystems since the 1980s and is obliged to report this information to the United Nations Framework Convention on Climate Change.

Forest canopy carbon assimilation (photosynthesis) can be measured directly using portable infrared gas analyzers or quantified indirectly by measuring forest canopy water uptake (transpiration = water flux = sapflow). Plants combine carbon dioxide ( $\text{CO}_2$ ) from the atmosphere with water extracted from the soil to form sugars (plant food). Portable  $\text{CO}_2$  gas analyzers are used to measure foliage carbon dioxide uptake by various tree species; photosynthetic rates are calculated by using a real-time computer that considers numerous measured environmental and tree physiological variables in the calculations. These same analyzers, equipped with a soil chamber instead of a leaf chamber, can also measure carbon dioxide emissions (soil respiration) from the soil. Transpiration (water flux = sapflow) is measured by temperature-sensitive probes inserted into the sapwood of trees. The sapwood is the tree's internal plumbing for transporting water taken from the soil by the roots. The water is then transported via the sapwood to the foliage where carbon assimilation (photosynthesis) occurs. The rate of sapflow is measured by electrically heating the water as it passes the first probe and then remeasuring the temperature as the water passes a second probe. The change in temperature of the water translates to a rate of water flow. If this rate of flow is known then a rate of canopy photosynthesis can be indirectly calculated without directly measuring  $\text{CO}_2$  uptake using a  $\text{CO}_2$  analyzer.

All of these measurements require complex procedures, which are performed with the aid of specialized instruments. Carbon fixation is measured with a portable infrared gas analyzer, known as the LiCor 6400 Photosynthesis System (Image 1), which provides a measure of gas exchange at controlled temperature and light conditions. These data are combined with meteorological data and leaf area data to model annual carbon assimilation on a stand basis. Sapflow, or transpiration, is measured with Dynamax TDP 30 mm probes, (Image 2) which are inserted into the sapwood of the tree to measure the volume of water uptake on a daily basis.

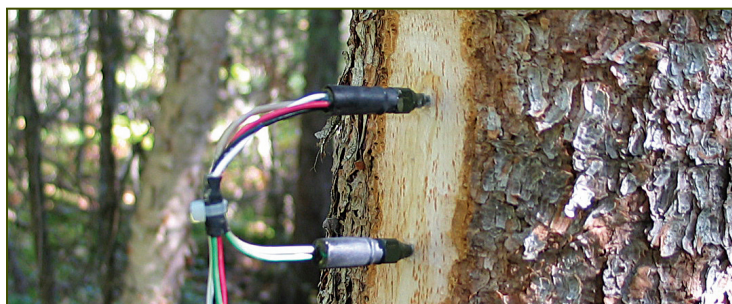
### GREAT LAKES FORESTRY CENTRE (GLFC) ROLE

The boreal mixedwood forest of Northern Ontario is being studied at three research sites (Groundhog River, McKeown Lake, Childerhose plantation) of different ages providing a chronosequence of forest growth (Table 1). All three monitoring sites are managed by Queen's University and the CFS, GLFC. The GLFC has prime responsibility for the McKeown Lake site.

A control site of mature mixedwood forest, known as the Groundhog River site near Foleyet, Ontario, is representative of the oldest stage (80 years) in the chronosequence and will not be harvested. The middle of the chronosequence is represented by the Childerhose Flux station site, near Timmins, Ontario, where a 25-year-old plantation of black



**Image 1.** The LiCor 6400 provides a measure of gas exchange at controlled temperature and light conditions. (Photo G. Brand)



**Image 2.** Sapflow, or transpiration, is measured with Dynamax TDP 30 mm probes. (Photo G. Brand)

and white spruce is being monitored. The McKeown Lake site was monitored at ground level (sapflow and leaf area index) for 4 years before being harvested in the winter of 2009 at age 75. At the McKeown site the forest will be either regenerated naturally or replanted.

**Table 1.** Northern Ontario Flux Stations

Site	Predominant Species	Soil Drainage
Groundhog River	Trembling aspen, white birch, white spruce, balsam fir and black spruce	Poor
Childerhose township	White & black spruce (planted) balsam fir, white birch, and trembling aspen (natural regeneration)	Moderately good
McKeown Lake	White birch, white spruce, trembling aspen, balsam fir and black spruce	Moderately good

Work is also being carried out at an auxiliary site in Wells Township, located near Thessalon and Wharncliffe, Ontario by scientist Phil Reynolds, where a 16-year-old jack pine plantation, growing on a well-drained sandy loam that had been subjected to varying harvesting and site preparation treatments, is being studied as part of the North American Long Term Site Productivity Survey (LTSP). The LTSP sites form a network of collaborative research sites across North America where long term effects of forestry practices on site productivity are monitored. Information gathered from the Wells Township site will allow comparison of carbon assimilation between different silvicultural regimes, which represent a gradient of nutrient removal and soil compaction.

Phil Reynolds has been studying carbon cycling in individual trees at all of these sites with the goal of obtaining estimates of carbon assimilation on a per hectare basis. He has also compared carbon assimilation by the tree canopy (photosynthetic uptake) to that calculated from canopy transpiration (water flux, sapflow), which gives an indirect estimate of carbon assimilation. These calculated amounts of carbon assimilation can be compared to the flux tower measurements (refer to Frontline Express Note 42) and differences in tree age, size and species can be studied and accounted for when scaling up to a stand-level calculation of carbon uptake. Intensive sampling, which includes a population inventory of the numbers and stem diameters of each species of trees, is done at all sites.

Results show variability between species in the optimal temperature for photosynthesis (Table 2) as well as variation throughout the growing season. For example, while jack pine could assimilate carbon at 10°C, the rate was higher in the fall when the soil was warmer than in the spring following snowmelt. It appears that species occupy different niches in the growing season for carbon assimilation. Hardwoods use the summer months and conifers have greater assimilation in the spring and fall when the deciduous trees are not in leaf.

At all sites, the volume of water uptake and measured photosynthesis by hardwoods was 3-4 times greater than for conifers. This can be attributed to the width of the sapwood, which is much greater in hardwoods. The volume of water uptake was directly related to the diameter of the tree, with larger trees having a greater capacity for uptake. For the conifer species, both black and white spruce drew greater water volumes from the soil than balsam fir. These species trends closely matched the results for carbon assimilation rates using the leaf photosynthesis measurements, with sapflow by conifers sustained in the shoulder seasons when the hardwoods were not

**Table 2.** Optimal temperature for photosynthesis by species

Species	Optimal temperature for photosynthesis (°C)
balsam fir	10-15
black spruce	15-20
white spruce	20-25
jack pine	20-25
white birch	30
trembling aspen	35

in full leaf. Results indicate that this indirect method of estimating carbon assimilation is a viable technique.

At the Wells Township site, where carbon assimilation was compared across a range of treatments with varying intensities of site preparation and biomass removal, results showed a decrease in the ability of a plantation to sequester carbon where site preparation treatments had been more severe, as in the case of compacting and blading.

## CONCLUSION

Data collected from this study is making a valuable contribution to the Canadian Carbon Program, as well as to the international Fluxnet research network. Results will help develop a scenario for carbon sequestration by boreal forests in a warming climate, such as the high potential for conifers to assimilate carbon in the spring and fall growing periods, which are predicted to lengthen. The observed negative effects of compacting and blading on carbon assimilation potential has important implications for forest management activities. To learn more about other aspects of Canada's Carbon Program please refer to Dr. Nick Payne, Frontline Express Note 42.

## COLLABORATORS

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## CONTACT INFORMATION

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