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CARBON FLUX FROM EARLY POST-FIRE SUCCESSIONAL FORESTS IN SASKATCHEWAN

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1. INTRODUCTION

The net annual carbon balance of the Canadian boreal forest is largely driven by current and previous disturbances that determine stand age, species composition, and carbon dynamics (Kurz and Apps 1999). Fire is one of the main stand renewal agents, with annual direct fire emissions averaging about 27 Tg C from about 2 million ha burned during the past four decades (Amiro et al. 2001). However, the indirect, post-fire carbon fluxes have not been well quantified, and are the subject of several current investigations (Amiro et al. 2002, Litvak et al. 2002). We have been estimating carbon fluxes following fires using towers (Amiro 2001), aircraft (Amiro et al. 1999) and through remote sensing/modeling approaches (Amiro et al. 2000) in support of national carbon modeling efforts. Our previous tower flux measurements were of short duration, and only offered a glimpse of the processes operating over a few weeks during the summer growing season. In the current paper, we present a longer series of carbon flux measurements collected during 2001 at two sites in the boreal forest of central Saskatchewan. The WASK98 site is a severe burn that occurred in 1998 (54º 05'N, 106º 00'W), which is now vegetated by numerous trembling aspen suckers to a height of about 1m with smaller regenerating jack pine and black spruce seedlings. Dead tree boles are still standing but there is also much deadfall and bare soil exposed. The ML89 site (54º 15'N, 105º 53'W) is about 20 km from the WASK98 site. The fire occurred in 1989 and the area is now vegetated by jack pine trees about 3 m tall with some trembling aspen, balsam poplar and black spruce. These sites are part of the BERMS (Boreal Ecosystem Research and Monitoring Sites, http://berms.ccrp.ec.gc.ca) area, an experiment that has continued since the BOREAS (Sellers et al. 1997) initiative.

2. METHODS

Carbon dioxide fluxes were measured on towers using the eddy covariance technique. All systems were battery and solar powered. The WASK98 site measurements were made at a height of 7.7 m using a closed-path LI6262 CO_2/water vapor sensor (LICOR Inc., Lincoln, NE) and a CSAT3 sonic anemometer (Campbell Scientific Inc., Logan, UT). The air stream was pulled down a 3-m length of 8-mm-ID Bevaline-IV tubing at a rate of about 5 L min^{-1}, and pushed into the analyzer. Corrections were made for lag in the tubing, frequency-response losses, temperature and pressure (Amiro 2001). The signals were sampled at 4 Hz; a previous comparison with a system operated by the University of British Columbia showed good agreement (Amiro et al. 2002). The ML89 site used an open-path system with a LI7500 (LICOR, Lincoln, NE) analyzer and a CSAT3 anemometer at a height of 5.2 m. The signals were sampled at 10 Hz and fluxes were corrected for density (Webb et al. 1980). Additional meteorological measurements at both sites included net radiation, air temperature, relative humidity, soil moisture, soil temperature, soil heat flux, sensible heat flux, latent heat flux, and incoming photosynthetically active radiation.

Half-hour CO_2 fluxes were calculated after coordinate rotations. Data were quality-controlled by eliminating night-time data when $u_* < 0.2$ m s^{-1} at the ML89 site, and <0.1 m s^{-1} at the WASK98 site. The lower u_* value for the WASK98 site was selected because the measurements were made at a height within the dead tree bole part of the canopy, and it is likely that our u_* measurement underestimates the total canopy momentum flux. Gaps in the night data were filled using an exponential regression relationship for night respiration above the u_* threshold with soil temperature (e.g., Black et al. 1996). Gaps in the remaining data were filled using average values of the previous and following five days measured at the same hour (e.g., Falge et al. 2000).

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3. RESULTS AND DISCUSSION

The WASK98 site was operated from April 4 to November 28, 2001, and the ML89 site ran from July 4 to November 28, 2001. Snow melt occurred during the first two weeks of April and snow fell during mid-November. At WASK98, 69% of the data passed quality-control and 668 records were used to develop the night respiration/soil temperature relationship that although statistically significant, had a r^2 value of only 0.11. At ML89, 60% of the data passed quality control, and the r^2 for night respiration/soil temperature was 0.34. Some gaps at ML89 were caused by rainy periods interfering with the open-path CO_2 sensor. The half-hour CO_2 fluxes were calculated using the direct eddy covariance measurement and CO_2 storage during the half-hour period using the change in mean CO_2 concentration at the top of the tower. We then expressed the fluxes in terms of daily net ecosystem production (NEP) as the negative value of the flux integrated over the day in units of g carbon $m^{-2}d^{-1}$. We plot NEP in Fig. 1 as weekly mean values through the season (positive values indicate a carbon gain).

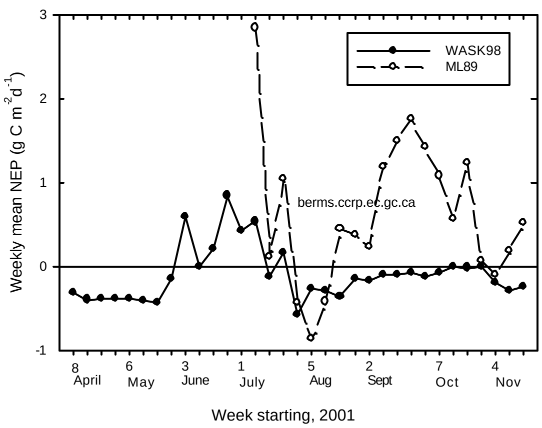

Fig. 1. Daily Net Ecosystem Production (NEP) at the WASK98 (burned in 1998) and ML89 (burned in 1989) sites. Weekly mean values are shown; positive values indicate a carbon gain by the forest.

The WASK98 site shows continuous respiration losses in the spring until the third week in May, when deciduous foliage develops. The site is a net carbon sink through much of June and July, but returns to a small carbon source through late summer and autumn. The fluxes are small throughout the 238 day measurement period with a net cumulative carbon loss of 24.5 g carbon m^{-2}. The ML89 site is a much larger carbon sink in early July, but it also becomes a carbon source in early August. By mid-August it returns to a carbon sink until the end of October. The site sequestered 104.6 g carbon m^{-2} through this 147-day period. The early August loss of carbon at both sites follows a period of rain and increase in soil moisture. Some of this net loss is caused by reduced daytime uptake, but we also see enhanced periods of respiration. We are currently evaluating the physiological mechanisms that could explain this summer pattern.

Previously we had only limited summer-time data on these same sites (Amiro et al. 2002). These data indicated that a two-year-old burn had a net daily balance of about zero, whereas a ten-year-old burn was a net daily sink of about 1.3 g C $m^{-2}d^{-1}$. The longer seasonal data show that even the summer fluxes can be variable in these early successional sites, where changing conditions can cause the forest to be either a carbon source or sink. We do not yet have data at the ML89 site for the important part of the growing season in June, so it is difficult to predict the magnitude of the annual source/sink strength of this site. However, the WASK98 site data extended throughout the growing season, and we expect further carbon losses through the winter because of constant low respiration. Hence this site is likely to be a carbon source of about 50 g C m^{-2} over the year, estimated by assuming a daily respiration rate of about 0.2 g C m^{-2} for the remaining 127 days of snow cover.

4. REFERENCES

Amiro, B.D., MacPherson, J.I., Desjardins, R.L., Chen, J.M., Liu, J. 2002. Post-fire carbon dioxide fluxes in the western Canadian boreal forest: evidence from towers, aircraft and remote sensing. Agric. For. Meteorol. (in press).

Amiro, B.D., Todd, J.B., Wotton, B.M., Logan, K.A., Flannigan, M.D., Stocks, B.J., Mason, J.A., Martell, D.L., Hirsch, K.G. 2001. Direct carbon emissions from Canadian forest fires, 1959 to 1999. Can. J. For. Res. 31, 512-525.

Amiro, B.D. 2001. Paired-tower measurements of carbon and energy fluxes following disturbance in the boreal forest. Global Change Biol. 7, 253-268.

Amiro, B.D., Chen, J.M., Liu, J. 2000. Net primary productivity following forest fire for Canadian ecoregions. Can. J. For. Res. 30, 939-947.

Amiro, B.D., MacPherson, J.I., Desjardins, R.L. 1999. BOREAS flight measurements of forest-fire effects on carbon dioxide and energy fluxes. Agric. For. Meteorol. 96, 199-208.

Black, T.A., et al. 1996. Annual cycles of water vapour and carbon dioxide fluxes in and above a boreal aspen forest. Global Change Biol. 2, 219-229.

Falge, E, et al. 2001. Gap filling strategies for defensible annual sums of net ecosystem exchange. Agric. For. Meteorol. 107, 43-69.

Kurz, W.A., Apps, M.J. 1999. A 70-year retrospective analysis of carbon fluxes in the Canadian forest sector. Ecol. Appl. 9, 526-547.

Litvak, M., Miller, S., Wofsy, S.C., Goulden, M. 2002. Effect of stand age on whole ecosystem CO_2 exchange in the Canadian boreal forest. J. Geophys. Res. (in press).

Sellers, P.J., et al. 1997. BOREAS in 1997: Experiment overview, scientific results, and future directions. J. Geophys. Res. 102(D24), 28,731-28,769.

Webb, E.K., Pearman, G.I., Leuning, R. 1980. Correction of flux measurements for density effects due to heat and water vapour transfer. Quart. J. Roy. Met. Soc. 106, 85-100.

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