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THE IMPACT OF HARVESTING AND FIRE ON ENERGY AND CARBON FLUXES IN THE BOREAL FOREST

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1. INTRODUCTION

Fire is the main stand-renewing agent in the Canadian boreal forest, typically burning about 1% of the forest area annually (Weber and Stocks 1998). As a major disturbance, fire controls much of the net carbon balance of the forest on time scales of decades (Kasischke et al. 1995, Kurz and Apps 1999). We estimate that the Canadian forest fires released an average of 27 Tg C year^{-1} as direct emissions during the past four decades, with individual years ranging from 3 to 115 Tg C year^{-1} (Amiro et al. 2000a). However, many models estimate that post-fire carbon fluxes are about equal to the direct emissions. These post-fire carbon losses are caused by decomposition of fire-killed vegetation and lower primary productivity of the new successional vegetation for the first few decades. Harvesting also impacts the forest and information on carbon dynamics can help in the design of forest practices to minimize carbon loss. Despite the modeling estimates, measurements are lacking on post-fire and post-harvesting carbon fluxes, and our goal is to gather the necessary data to validate and improve carbon budget models.

In addition, the large area burned (single fires can be 1 million ha in size) has local effects on the meteorology and climate of burned sites, largely caused by changes in the vegetation. There are few micrometeorological measurements of the effect of forest fires (e.g., Rouse 1976) so we also are investigating changes to the energy balance following fire and harvesting.

2. METHODS

The eddy covariance technique was used with paired towers to measure fluxes simultaneously at disturbed and undisturbed sites over periods of about one to two weeks during the growing season of 1998 and 1999. The disturbances were: a one-year-old burned jackpine stand at the International Crown Fire Modeling Experiment site that experienced an intense crown fire near Fort Providence, Northwest Territories(www.nofc.forestry.ca/fire/frn/nwt); a one-year-old clearcut aspen area at the EMEND project near Peace River, Alberta (www.biology.ualberta.ca /emend/index.htm); and a ten-year-old burned, mixed forest near Prince Albert National Park, Saskatchewan. Nearby mature forest stands of the same types were also measured as controls. Measurements were typically made just above the canopy, varying in height from 3 to 25 m, depending on the site.

3. RESULTS AND DISCUSSION

The harvested site had lower net radiation (R_n), sensible (H) and latent (LE) heat fluxes, and greater ground heat fluxes (G) than the mature forest. Daytime CO_2 fluxes were much reduced (Fig.1), although positive, but night-time CO_2 fluxes were identical to those of the mature aspen forest. It is hypothesized that the aspen roots remained living following harvesting, and dominated soil respiration. The overall effect was that the harvested site was a carbon source of about 2.4 g carbon m^{-2} day^{-1}, while the mature site was a sink of about –4 g carbon m^{-2} day^{-1}. The one-year-old burn had lower R_n, H and LE than the mature jackpine forest, and had a continuous CO_2 efflux of about 0.8 g carbon m^{-2} day^{-1} compared to the mature forest sink of -0.5 g carbon m^{-2} day^{-1}. The carbon source was likely caused by decomposition of fire-killed vegetation. The 10-year-old burned site had similar H, LE, and G to the mature mixed forest site. Although the half-hour CO_2 fluxes were slightly less, there was no significant difference between the daily integration (-1.3 g carbon m^{-2} day^{-1} at mature site and –2.9 g carbon m^{-2} day^{-1} at 10-year-old burn site).

These limited tower data indicate that most of the decrease in post-disturbance carbon flux occurs within the first ten years. However, flux measurements from aircraft at the landscape scale indicate that the forest takes about 30 years to recover (Amiro et al. 1999). Also, remote sensing and modeling estimates of net primary productivity (NPP) at a larger scale show a linear NPP increase with time since fire for the first 15 years, with a

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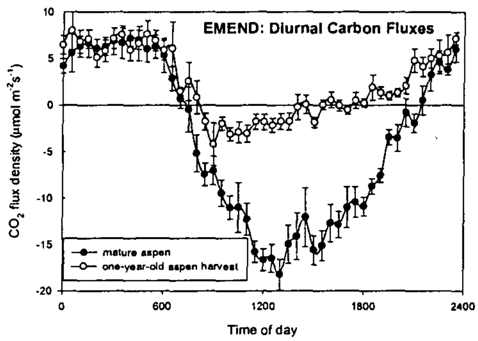
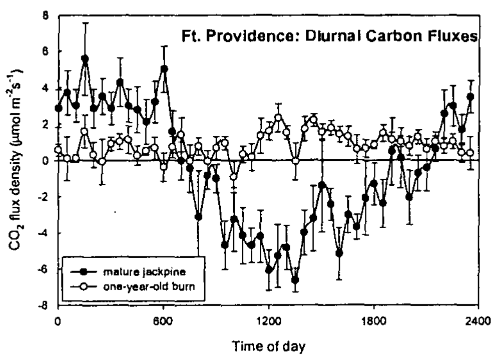
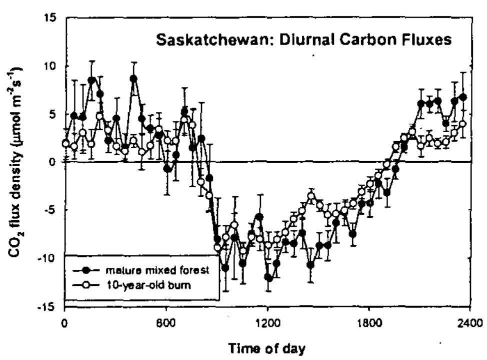
steady state situation achieved at between 20 and 30 years in some areas (Amiro et al. 2000b).

Fig. 1: CO_2 flux comparisons at three disturbed sites. Negative values are downward fluxes.







The paired-tower method allows direct comparison of fluxes from different treatments. This answers many of the questions about relative fluxes, but a much longer record period is needed at these sites to account for intra- and inter-annual variability. Unfortunately, it is difficult to maintain long-term monitoring at many sites, and our approach to date has been to move the paired towers among different sites to gather data on disturbance type and age. This allows for chronosequence data to be gathered over a relatively short period with few resources. Data still need to be gathered for more stand types focusing on the one- to 10-year period following disturbance in deciduous forests (e.g., aspen that regenerates quickly by suckering), and on the five- to 15-year period in coniferous forests where seeding and regeneration take slightly longer. We still need to identify the relative magnitude of the processes, since modelers often separate mechanisms such as photosynthesis, autotrophic respiration and decomposition. The present study give clues about the net carbon flux, but raises many more questions about the components.

4. ACKNOWLEDGMENTS

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