P1.16 NET ECOSYSTEM PRODUCTIVITY FOLLOWING FIRE IN THE CANADIAN BOREAL FOREST

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1. INTRODUCTION

Fire and harvesting are considered as two of the major disturbances driving the net biome production in the Boreal Forest. About 2 million ha of forests burn in Canada per year, and more than 7 million ha burn during extreme fire years. Climate change projections for Canada suggest that the forest area burned will double by end of this century (Flannigan et al. 2004). In addition to the carbon directly released to the atmosphere during a forest fire, there is a need to assess the carbon balance of the vegetation established after a fire. The Net Ecosystem Productivity (NEP) is a measure of the residual annual carbon incremented (or lost) to the long-term carbon stocks of any given region. As such, it represents a critical variable in determining the long-term behaviour of the terrestrial carbon cycle.

2. OBJECTIVES

As members of the Boreal Ecosystem Research and Monitoring Sites (BERMS), a component of the Fluxnet-Canada network, a collaboration among university and government scientists, we share a long term, ongoing objective: to determine the net ecosystem exchanges of radiation, sensible and latent heat, and carbon dioxide in Canadian boreal forests. In our particular study, we measure NEP following fire in three forest sites in central Saskatchewan.

3. MATERIALS AND METHODS

We measured the exchange of radiation, sensible heat, water vapour, and carbon dioxide, and meteorological variables, following the Fluxnet-Canada Protocol for Eddy Covariance Flux Measurements, and the Protocol for Meteorological Variables Measurements (Fluxnet-Canada Network Management Office, Faculté de Foresterie et de Géomatique, Université Laval, Québec, Canada. August 2003). The sites were forests burned in 1998, 1989 and 1977 (98F, 89F and 77F), located in the boreal plains of Saskatchewan near Waskesiu Lake (54° 15'N 105° 53'W), Montreal Lake (54° 15'N, 105° 53'W), and Weyakiwin Lake (54° 29'N 105° 49'W), respectively.

The 98F site (Picture 1), established in 2001, is characterized by numerous trembling aspen suckers to a height of about 1 m, with smaller regenerating jack pine and black spruce seedlings. Dead tree boles are still standing but there is also much deadfall and soil exposed.

Picture 1. The 1998 forest-fire site (98F) in Prince Albert National Park, Central Saskatchewan.

The 89F site (Picture 2), also established in 2001, is vegetated by jack pine trees, about 3 m height, with some trembling aspen, balsam poplar and black spruce. The 77F site (Picture 3), established in the summer of 2003, is characterized by an average canopy height of about 7.5 m, composed mainly by jack pine as the tallest trees, and black spruce in the sub-canopy.

Picture 2. The 1989 forest fire site (89F) near Montreal Lake, Central Saskatchewan.

The carbon dioxide (CO_2) fluxes are calculated based on high frequency (10 Hz), measurements of vertical wind velocity, air temperature and CO_2

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density, following the eddy covariance method. The instantaneous vertical wind speed is monitored with CSAT3 three-dimensional sonic anemometers (Campbell Scientific Inc. Logan, UT) in all three sites. Half-hour means of CO_2 fluxes are expressed in terms of NEP, and defined as –NEE, Net Ecosystem Exchange, after gap-filling all data not meeting a site-specifically derived *u** threshold, mostly during nigh-time. NEP fluxes were computed after coordinate rotation, air and water vapour density corrections and the inclusion of the CO_2 storage term. In the 98F site, CO_2 densities were measured at a 7.7 m height from April 2001 to August 2002 with a closed-path (LI 6262, LICOR Inc. Lincoln, NE) IRGA analyzer. From August 2002 to present, CO_2 densities were measured at a 20 m height with an open path (LI 7500 LICOR Inc., Lincoln, Nebraska), IRGA analyzer. In both the 89F and 77F sites, CO_2 densities are measured with open path IRGA analyzers at 9.1 and 12.1 m height, respectively.

Picture 3. The 1977 forest-fire site (77F) near Weyakiwin Lake, Central Saskatchewan

4. RESULTS AND DISCUSSION

Figure 1 shows daily NEP (g C m^{-2} day^{-1}) and growing season (June, July and August (JJA)) total NEP (g C m^{-2} JJA^{-1}). The daily NEP in the 98F site shows a period of CO_2 sequestration lasting through June in all three years of measurements. However, inter-annual variability is evident when comparing the total NEP during the JJA growing seasons, turning from a slight source in 2001 to a sink in the summer of 2003. In the 89F site, the daily NEP during the springs of 2002 and 2003 indicates well-defined periods of CO_2 sequestration lasting from mid-April (snowmelt) through the end of June, explained in part by the strong development of trembling aspen foliage.

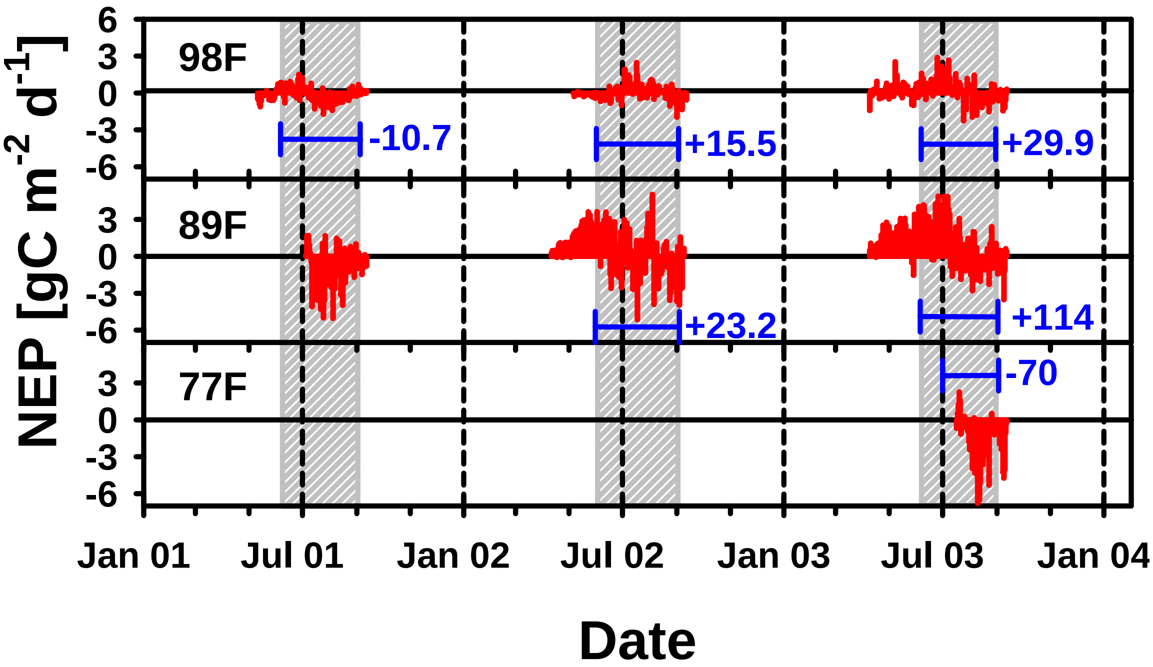

Figure 1. Daily (g C m^{-2} day^{-1}) and growing season (June, July and August) NEP totals (g C m^{-2} JJA^{-1}) in a chronosequence of forest fires dated 1998, 1989 and 1977.

The 89F forest gained 8 g C m^{-2} JJA^{-1} more than the 98F forest during the JJA season of 2002, and 84 g C m^{-2} JJA^{-1} the following and wetter growing season. The 77F site started operating on July 18, 2003, precluding the JJA growing period comparisons among the three sites. The NEP flux in this site turns from a strong CO_2 sink by mid-July, to a strong CO_2 source, through the rest of the growing season, releasing –70 g C m^2 $month^{-1}$ during August 2003. The younger forest fire sites were also a source of CO_2 during the same period, releasing –5 and –13 g C m^2 $month^{-1}$ in the 89F and 98F sites, respectively.

We have not shown winter data here since we have been experiencing suspicious measurements with the open-path analyzer during winter. We often measure downward CO_2 fluxes in an ecosystem where only net respiration is expected. We have not yet found the cause for this. However, by gap-filling winter data using measurements from nearby mature forest sites, we estimate that the 98F is a moderate carbon source, whereas the 89F site is a moderate carbon sink, annually (Amiro et al. 2004).

5. CONCLUSIONS

The two youngest forest-fire sites under study are mainly populated by deciduous and herbaceous cover, in contrast to the coniferous vegetation characterizing the oldest forest-fire site. This vegetation difference controls much of the seasonal carbon dynamics. From snowmelt and to the end of growing season, the NEP values shifted every year from a mild-source to a strong sink and back to a strong source. The patterns observed in both 98F and 89F are similar, both acting as CO_2 sinks during the early and mid-growing season when the herbaceous vegetation is being established and the aspen leaves emerge. The magnitude of CO_2 sequestration is much larger in 89F than in 98F due to a larger leaf area index at the older fire site. Later in the growing season, the fire chronosequence indicates the three sites are CO_2 sources to the atmosphere, with the strongest source at 77F, the oldest forest-fire site. In contrast with harvesting, fire removes the finer material while leaving the killed trees standing. This organic material would not be a significant contribution to the heterotrophic respiration until it is subject to decay once resting on the ground and fully exposed to moisture and soil fauna, in a process that may take several years to get started.

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