6.6 COMPARING CARBON DIOXIDE AND ENERGY FLUXES FROM MATURE AND CLEAR-CUT WEST COAST DOUGLAS-FIR FORESTS

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1. INTRODUCTION

Changes in climate and land use that affect forests are expected to have important consequences on the global carbon (C) budget (Woodwell et al., 1983). This is a result of both the significant exchange of CO_2 between terrestrial biota and the atmosphere and of the large C stocks found in forest soils and vegetation (Schlesinger, 1997). In British Columbia, Canada, four years of long-term eddy correlation measurements of CO_2 fluxes above a mature 2nd growth coastal Douglas-fir forest have shown this stand to be a strong C sink, 4.1 ± 0.4 t C ha^{-1} y^{-1}, subject to significant interannual variability (Morgenstern et al., 2001). However, the interannual and seasonal C sink/source strength of this forest type after disturbance in the form of harvesting and subsequent planting has not been investigated.

We compare, from August 15, 2000 to December 31, 2001, CO_2 and water vapour exchange between the atmosphere and two Douglas-fir stands at different stages of growth: the above mature 2nd growth stand and a recently replanted clear-cut. The two sites are within 3 km of one another in the same biogeoclimatic zone experiencing similar weather. Having reduced the differences in synoptic scale weather forcings, we investigate the interacting influences of forest cover, microclimate and surface energy fluxes on CO_2 exchange.

2. METHODS

The study sites are located on the east coast of Vancouver Island, B.C., Canada (49°52'N, 125°20'W). The mature Douglas-fir site (MF) is a dense stand (1105 trees ha^{-1}) of 55 y-old trees located at an elevation of 300 m on a 5 to10° NE-facing slope. The clear-cut site (CC) was harvested in the winter of 1999/2000 and planted with 1-y-old Douglas-fir (93%) and cedar (7%) in March 2000. This site is at an elevation of 180 m with < 2° terrain slope.

Total flux densities of CO_2 (F_c), latent heat (λE) and sensible heat (H) were measured using the eddy covariance method. Half-hour covariances of vertical velocity and scalar constituents were calculated at MF from data down-sampled to 20.8 Hz on a PC (see Humphreys et al. (2002) for more details) and from data collected at 10 Hz using a datalogger (model 23X, Campbell Scientific Inc., Logan, UT) at CC. At MF, high-frequency H_2O and CO_2 were measured using a closed-path infrared gas analyzer (IRGA) (model LI-6262, LI-COR Inc., Lincoln, Nebraska) and converted to mixing ratios prior to calculating fluxes, while an open path IRGA (model LI-7500, LI-COR Inc.) measured mass densities at CC and required WPL corrections on the fluxes for density effects. No spectral corrections were applied to the fluxes from either site.

Half hour fluxes determined with an open-path IRGA were compared to closed-path fluxes both measured at 20.8 Hz under clear-sky conditions in June at MF. The regression forced through zero indicated that open-path F_c was 4% greater, while λE was 8% lower than closed-path fluxes (n = 329, R^2 = 0.94 and 0.95, respectively). After removing bad data due to sensor error and malfunction, energy budget closure determined by the linear regression of all half hour $H+\lambda E$ against available energy (net radiation - energy storage - soil heat flux) was 76% at MF (R^2 = 0.88, n = 22148) and 89% at CC (R^2 = 0.91, n = 13272).

Net ecosystem exchange (NEE) was computed using the sum of half hour F_c and CO_2 storage within the air column below the measurement height. Missing NEE measurements were filled using mean diurnal variation over 14-day windows, while measurements during calm periods at night were replaced using an exponential relationship between nighttime NEE (equal to respiration, R) and 5 cm soil temperature (T_s) (see below).

3. RESULTS AND DISCUSSION

There were no significant differences (α < 0.001) between mean downwelling shortwave radiation, air temperature, water vapour pressure and rainfall measurements at MF (at 45 m) and CC (at 8 m). As expected, the difference in forest cover was a dominant factor influencing differences in microclimate variables. Snow-free, midday albedo was 0.07 ± 0.04 at MF where the stand leaf area index (LAI) was 6.7 m^2 m^{-2}. In contrast, the mean albedo at CC was 0.16 ± 0.03 associated with a growing season maximum LAI of 0.27 m^2 m^{-2} in 2000 and 0.87 m^2 m^{-2} in 2001. Summer and winter T_s at CC exhibited a greater diurnal amplitude and seasonal variability ranging from -1.7 °C to 34.5 °C. On average, T_s was 2.5 °C cooler and ranged from 0.7 °C to 16.6 °C at MF. Preliminary results show total uncorrected evaporation to be very similar at the two sites from January to the end of June, 2001 (182 mm at MF, 177 mm at CC). However, the top 30 cm of soil became significantly drier at CC in early July 2001 (α < 0.01) with minimum water content readings of 0.068 m^{3}m^{-3} compared to 0.11 m^{3}m^{-3} at MF. Consequently, evaporation was lower through the rest of the summer at CC and resulted in a lower annual evaporation of 328 mm compared to 385 mm at MF.

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Fig. 1 illustrates the exponential relationship between R and T_s excluding data measured when friction velocity was less than 0.3 m s^{-1} at MF and 0.09 m s^{-1} at CC. The resulting Q_{10} was 4.8 at MF and 2.1 at CC. Although the larger Q_{10} at MF is difficult to interpret, respiration from the forest biomass at MF was expected to result in greater ecosystem R for any given T_s when compared to CC.

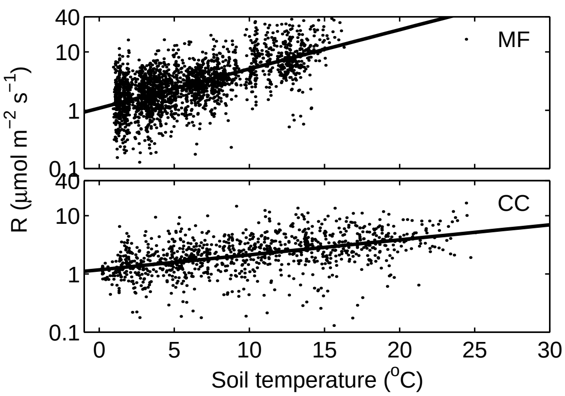

Figure 1 Nighttime R vs. 5 cm soil temperature in 2001.

Daily NEP (-NEE) from August 2000 to the end of December 2001 is shown in Fig. 2. In 2001, NEP was 4.3 ± 0.2 t C $ha^{-1}y^{-1}$ for MF and -6.5 ± 0.2 t C $ha^{-1}y^{-1}$ for CC (± 1 SE based only on 10% random error in F_c and the SE associated with model parameters). At MF, high LAI and the mild coastal climate resulted in daytime C uptake throughout the year. The greatest 24-h net C uptake rates occurred during May when respiration remained relatively low compared to gross ecosystem production due to cool temperatures and abundant light.

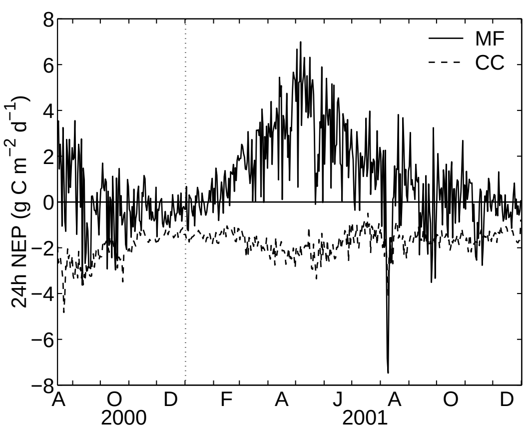

Figure 2 24 h nighttime corrected NEP at MF and CC from August 15, 2000 to December 31, 2001.

The clear-cut was a net source of C all year (Fig 2). Carbon losses were lowest in winter when soil respiration was inhibited by near-freezing conditions (Fig. 2). On average, the net daily C losses were also lower throughout August and September 2001 when compared with the same time in 2000 (Table 1). The relationship between nighttime R and T_s was not significantly different between the two years during this period. The drier soil conditions in 2001 did not seem to impact nighttime soil R, rather, reduced C loss in 2001 was related to the growth of weed species and their photosynthetic uptake, estimated at 1.6 g C m^{-2} d^{-1}.

Table 1 Average NEP, gross ecosystem production (GEP = NEP + R) and R for 47 days in 2000 and 2001 at CC. Average daily R is determined using the relationship between measured nighttime R and 5 cm soil temperature for each period and is positive for C losses from the system. NEP and GEP are positive for C uptake by the system.

Time Interval	NEP	GEP (g C m^{-2} d^{-1})	R
Aug 15-Sept 30, 2000	-2.8	0.4	3.2
Aug 15-Sept 30, 2001	-1.6	1.6	3.2

4. CONCLUSIONS

In 2001, the net loss of C from the clear-cut, per unit surface area, was greater than the net assimilation of atmospheric C by the mature forest. However, there is some evidence for a weakening of the clear-cut's CO_2 source strength. We observed a reduction in the CO_2 released from the clear-cut one year after the measurements began. This is apparently due to an increase in photosynthetic uptake of C as the vegetation recovers after harvest.

5. REFERENCES

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