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P2.15 A PRELIMINARY INTERCOMPARISON OF MICROMETEOROLOGICAL AND ECOLOGICAL ESTIMATES OF CARBON SEQUESTRATION IN A MID-LATITUDE DECIDUOUS FOREST FOR 1998 AND 1999

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1 INTRODUCTION

Net CO_2 exchange can be measured on an annual basis, using eddy covariance techniques or from ecological inventories of various C compartments. Here we present an inter-comparison of annual estimates of C sequestration for 1998 and 1999 in a mixed hardwood forest in the Morgan-Monroe State Forest, Indiana, USA. Eddy covariance estimates were made at 1.8 times canopy height. For the same time period, ecological measures and model estimates of change in living biomass, sum of aboveground and belowground detritus production, consumption, and forest floor and soil respiration were made. The aim is to determine the consistency of spatially and temporally integrated estimates of net C sequestration for one-year periods for both 1998 and 1999, and to examine the inter-annual variability of estimates for those periods. Annual values calculated for both methods are for the time period (year/day) 98/60 – 99/59, and 99/1 – 99/365.

2 METHOD

2.1 *Study Site*

Morgan Monroe State Forest (MMSF) lies just south of the limit of the late Wisconsinan glaciation and is dominated by ridge/ravine topography. The region is covered primarily by secondary successional broadleaf forests located within the maple-beech to oak-hickory transition zone of the Eastern Deciduous Forest (Braun, 1950). Tree species composition at MMSF is estimated based on a survey of all trees with a diameter at breast height (dbh) of ≥ 7 cm in 54 rectangular plots (150 m^2 each) established with a stratified random distribution in the vicinity of the tower. In these plots, 29 tree species have been identified, but nearly 75% of the total basal area is composed of sugar maple, tulip poplar, sassafras, white oak, and black oak.

Timber harvests in the vicinity of the flux tower are predominately selective cuts, and have occurred on 20-25 year rotation for several decades. In addition to past harvests, patches of the forest in the tower area were impacted by a 1990 windstorm, with the effect that most of the forest is not fully mature. Overall, the forest is closed canopy, dominated by 60-80 year old trees. The minimum forest fetch exceeds 4 km, and MMSF has a total area of 95.3 km^2.

2.2 *Intercomparison Procedures*

Net CO_2 exchange can be measured on an annual basis, based on eddy covariance flux above the forest. This flux represents net ecosystem production or exchange (NEP or NEE, where NEE integrated over a year is annual NEP; NEE is positive upward; NEP is positive for net carbon uptake), indicating net C sequestration. NEP captures a host of vegetation and soil processes and feedbacks associated with C metabolism, including the magnitude of whole system photosynthesis and respiration, and responses of ecosystems to climate variation and other perturbations. NEP is related to net primary production (NPP) by:

$$NEP = NPP - R_h \quad (1)$$

where R_h is heterotrophic respiration (microbes and soil fauna), which in addition to the root component (R_r) constitutes total soil respiration (R_s):

$$R_s = R_h + R_r \quad (2)$$

An alternative approach to the estimate of NEP by eddy covariance is the calculation of NEP from inventories of C compartments and process-level flux measurements. The following relation (Waring and Schlesinger, 1985) can be used for NEP estimation, in conjunction with (1):

$$NPP = \Delta B_{living} + D_{tot} + \text{Consumption} \quad (3)$$

where ΔB_{living} is the change in living biomass, D_{tot} is the sum of above- (D_a) and belowground detritus production (D_b), and Consumption is equated to aboveground leaf herbivory.

Estimation of ΔB_{living}, relies heavily upon allometric relationships relating tree biomass with easily measured parameters, such as dbh. Litterfall and fine root turnover data are necessary to estimate detritus production. Leaf herbivory data are required to estimate consumption. Modeled, annual soil respiration rates as well as estimates of the root respiration (R_r) component of R_s are necessary to estimate the last term in (1).

While eddy covariance has the capacity to yield annual NEP estimates it can also provide estimates of NEE for shorter time intervals. There are problems trying to use ecological (bottom-up) approaches at time scales shorter than the annual cycle. While tree diameter growth derived from dendrometer data might be used to predict growth during the year, other components needed for the calculation of NEP do not support a similar temporal resolution. Thus, inter-comparison here is limited to annual estimates of C sequestration only.

Due to differences in measurement approach, sensor position and technology, the micro-meteorological and ecological exchange and inventory measurements refer to different fields-of-view or footprints. To compare the different measurement classes, the footprint of the atmospheric measurements needs to be spatially or statistically consistent with the locations sampled in the ecological inventory. Inherent is the assumption that

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both estimates have appropriately sampled the spatial variability of the ecological processes in that they are representative samples of the exchange processes on the ecosystem scale (Schmid and Lloyd, 1999).

Full details of instrumentation, data processing and results of diurnal and seasonal variations of energy and CO_2 fluxes are provided in Schmid *et al.* (2000a). Full details of the ecological inventory method are provided in Ehman *et al*. (1999, 2000).

3 RESULTS

3.1 *Results from Atmospheric Flux Measurements*

Hourly micrometeorological data are analyzed as described in Schmid *et al*. (2000a). Data gaps are filled and eddy fluxes are replaced by parametric models of ecosystem respiration and gross ecosystem production during times of poorly developed turbulence. Using similar methods for both years, the micrometeorological estimates of NEP are 237 g C m^{-2} a^{-1} for 1998, and 380 g C m^{-2} a^{-1} for 1999 (Schmid *et al*. 2000b).

3.2 *Results from Ecological Inventory Measurements*

Period	1998	1999
Change in Biomass	**-225.2**	**-302.8**
Boles and branches	-202.4	-276.7
Central stump & main lateral roots	-15.3	-18.6
Secondary lateral roots	-7.5	-7.5
Detritus Production	**-706.3**	**-719.9**
Herbaceous plants	-10.2	-11.4
Tree leaves	-195.8	-207.9
Tree seeds	-13.8	-14.1
Fine roots	-486.5	-486.5
Consumption (Leaf herbivory)	**-14.3**	**-13.7**
Heterotrophic Respiration	**695.3**	**602.9**
Forest Floor and Soil	603.8	520.5
Large Woody Debris	91.5	82.4
Net Flux	**-251**	**-434**

Table 1: MMSF component fluxes from ecological inventory method. All units are *g C* m^{-2} a^{-1}.

Individual fluxes are presented in Table 1. Two inter-annual differences in the component fluxes are noteworthy. First, the much larger ΔB_{living} value for 1999 suggests that the severe drought (see Grimmond *et al*., 2000; Schmid *et al*., 2000b,) did not hinder tree growth in that year. The earlier "leaf-on" date in 1999, as evident in bole expansion measured with dendrometers, is more likely the difference. Second, the severe drought and resultant soil moisture conditions did affect a large change in the soil respiration model estimates.

3.3 *Comparison of annual total carbon sequestration estimates*

The inventory methods suggest that 1998 production is balanced by decomposition (i.e., respiration), and the net C flux roughly equals the ΔB_{living} term. In that year, there is a 6% difference in estimates between the two methodologies. This discrepancy in NEP estimates rises only to ~13% for 1999. One possible explanation for this is the use of 1997 fine root stock measurements in the calculation of fine root production for both the 1998 and 1999 flux estimates. It is likely that the severe drought in 1999 would have to some degree reduced fine root production below its modeled value, and thus brought the overall inventory-based estimate closer to that of the eddy-correlation technique.

These relatively small differences suggest that some confidence can be placed in both approaches, despite inherent, but not easily quantifiable uncertainties. The atmospheric flux had to be modeled for periods of poorly developed turbulence and missing data. Possible complications due to drainage flow and mesoscale circulations are only starting to be explored. The two largest terms in the ecologically-based method for NEP, fine root production and the heterotrophic component of below ground respiration (Table 1), are both modeled estimates. Because of their relative magnitudes, small (%) changes in these terms dramatically change the net result. Further attention needs to be directed to the spatial representativeness of the ecological estimates and their spatial consistency with the footprint of the tower based atmospheric measurements. This issue is addressed in Ehman *et al*. (2000).

As additional data become available and sampling methodologies are refined, we expect a greater level of confidence in these terms and, possibly, a tighter correspondence between annual net C flux estimates between methods.

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