10.4 AGRICULTURAL CANOPY AND SOIL CO_2 RELEASE AND PHOTOSYNTHETIC RECAPTURE

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1. INTRODUCTION

New technology has provided the tools that allow for continuous monitoring of canopy photosynthesis, and thus an estimate of the total biomass fixed by a canopy during a growing season. Because the instruments are installed above the canopy, an implicit assumption is that the atmosphere is the source of all carbon (C) fixed by the canopy. It further assumes that all carbon dioxide (CO_2) released from the canopy and soil through respiration escapes from the canopy and is measured by the instruments above the canopy.

As part of NOAA's contribution to GEWEX, a continuous long term energy/carbon eddy covariance tower system was established on a no-till corn (Zea mays) and soybean (Glycine max) field in central Illinois. Continuous measurements of CO_2 and water vapor fluxes, energy balance, and weather data have been collected from corn and soybean crops since August 1996. In the summers of 1998 through 2001 destructive plant samples have been collected on a weekly basis from the canopy from which eddy covariance measurements have been made. The destructive plant samples provide an independent estimate of the C fixed by the canopy.

Comparison of the C fixed by the canopy from the eddy covariance measurements and the destructive sampling measurements show that the accumulated eddy covariance measurements underestimate the total C fixed by a canopy. The differences may be explained by either errors in the eddy covariance measurements, or by the above implicit assumptions being invalid.

There are two sources of CO_2 for a canopy, the atmosphere and the soil. The atmosphere is the only source of CO_2 above the canopy. Soil respiration is a continuous process that results in the evolution of CO_2 at the bottom of the canopy. During the night the CO_2 evolved from the soil is either captured within the canopy atmosphere or released to the atmosphere above the canopy. CO_2 captured in the canopy atmosphere during the night may be either quickly released to the atmosphere above the canopy, or fixed by photosynthesis soon after daylight. During the day when solar radiation is present, a portion of the CO_2 released from the soil may be fixed by photosynthesis. The CO_2 from the soil that is fixed is never measured by the eddy covariance instruments.

The objective of this work is to test the hypothesis that soil respiration is a major contribution to canopy biomass in an agricultural canopy, to explore different methods to estimate the source and quantity of recaptured CO_2, and to propose methods to more accurately estimate this important source of C.

2. METHODS

Eddy covariance measurements where made above the canopy during the summers of 1998 through 2001. During the summer of 1998 when soybean was grown in the field, canopy CO_2 concentration measurements were collected throughout the season in addition to the above canopy eddy covariance measurements. In the summer of 1999, a short term experiment was conducted when eddy covariance measurements were collected inside the canopy as well as above the canopy. Finally during the summer of 2001, soil CO_2 measurements were collected once a week during the growing season.

Destructive sample, taken once a week throughout the growing season, provide the "ground truth" for evaluating the total amount of C fixed by the canopy. The destructive sampling provided data on the above ground biomass only. To account for the root biomass, a model was developed using the data from Mayaki et al. (1976) that related root mass to final grain yield.

The methods used to estimate the amount of soil CO_2 available for recapture by photosynthesis include comparisons of day and night CO_2 exchange rates, within and above canopy eddy covariance measurements, estimates of soil respiration from soil CO_2 flux measurements, and soil respiration models.

3. RESULTS

The differences between estimates of C fixed in the biomass of a corn canopy (Figure 1) shows that summing all the carbon fluxes over the growing period

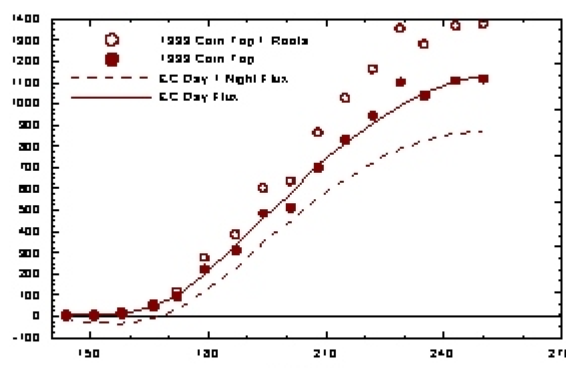

Figure 1. C fixed by a corn canopy. Circles are estimates from destructive sampling, dashed line is estimated by summing 30 minute CO_2 fluxes from planting to maturity, solid line is summing only day time CO_2 fluxes.

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underestimates the C fixed in the above ground plant parts. If only the CO_2 fluxes in the day time periods are accumulated the eddy covariance measurements do a good job of estimating above ground biomass. Accumulating carbon by summing the C fluxes for all time periods of the day accounts for approximately 63 percent of the total canopy biomass, while accumulations using only the day light hours accounts for 82 percent of the C fixed by the canopy.

If the night time eddy covariance CO_2 flux rates are used as a measure of soil respiration, the CO_2 efflux rate is estimated at 3 to 7 μmol m^{-2} s^{-1}. Soil chamber measurements of soil CO_2 efflux are a factor of two greater (7 to 15 μmol m^{-2} s^{-1}). With the chamber measurements the larger value was obtained as the canopy neared maturity and the smaller value was observed prior to corn pollination.

During the presentation results of the contribution of soil CO_2 from the estimates of canopy CO_2 concentration, in canopy eddy covariance measurements, soil CO_2 flux measurements, and model estimates of soil respiration will be shown. Finally the different methods used to estimate the contribution of soil CO_2 to the total biomass will be compared to the biomass measurements.

4. SUMMARY/CONCLUSIONS

Continuous eddy covariance measurements of CO_2 fluxes will underestimate the total C fixed in either a corn or soybean field. Thus eddy covariance alone cannot estimate the total carbon fixed by a canopy. The error is greater for a corn canopy than for a soybean canopy. In a corn canopy the error is approximately equal to the C fixed by the root mass. The most likely source of CO_2 for the biomass not measured by eddy covariance is from soil and root respiration.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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