ORAL 01

The Re-estimation of Annual Net Ecosystem Exchange of CO_2 with Standardized FLUXNET Eddy-covariance Data Processing in an Apple Orchard of South Korea

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I. Introduction

During the past decade, agricultural ecosystem sites have been established for measurements of CO_2, water vapor, and energy fluxes based on the eddy covariance method. Despite the continuous progress such as eddy covariance data processing in estimating those cycles, a number of potential flux errors remain unsolved. In particular, the eddy-covariance data process has not been implemented due to differences in approach by investigators in calculating half-hourly fluxes, controlling data quality, and gap filling the missing data due to highly heterogeneous landscape, complex topography, and humid climate (monsoon season). However, the eddy-covariance data quality have to determine with standardized data processing at each step of the quality control procedure for removal of uncertainties of flux data. The objectives of this study are to re-estimate annual net ecosystem exchange of CO_2 with standardized data process based on our scrutiny of the data observed at Uiseong apple orchard site in South Korea.

II. Materials and Methods

2.1. Study site

The study was carried out at about 15-year-old apple orchard at Uiseong (lat. 36° 23’ N 128° 49’ E) in South Korea. The topography of the site is flat and homogeneous land. The annual precipitation is 1392.6 mm and it rains mostly on July and August. The averaged air temperature ranges between –10.2°C (min.) and 27.3°C (max.).

2.2. Eddy covariance (EC) flux measurements

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EC measurement was taken from 1st November 2004 to 12th December 2007. Eddy covariance sensors were mounted on the tower of 10 meters height. The fetch area is estimated to be at least 1km diameter to the prevailing wind direction. The open path infrared gas analyser (LI-7500, Li-cor Biosciences Inc., USA) and three-dimensional sonic anemometer (CSAT3, Cambell Scientific Ins., USA) mounted at 7m. the net radiometer (CNR1, Kipp&Zone B.V., The Netherlands) mounted at 9m and air temperature and relative humidity probes (HMP45C, Cambell Scientific Ins., USA) mounted at 4m and 5m from ground. Soil temperature (TCAV, Cambell scientific, InC., USA), soil heat flux plate (HFP01, Cambell scientific, InC., USA), and soil water content reflectometer (CS615, Cambell scientific, InC., USA) placed horizontally at 10cm from the soil surface. A data logger (CR5000, Cambell Scientific Ins., USA) recorded the signal from EC measurement sensors (CSAT3, LI-7500) every 0.1 second and calculated every ten minute flux data. The environmental measurement sensors' data recorded and calculated every ten minute data.

2.3. Eddy covariance data processing

FLUXNET protocol was used as a standardized processing to calculate net ecosystem exchange of CO_2 and to remove uncertainty and potential error. The CO_2 flux data was corrected according to Webb *et al*. (1980) to neglect density fluctuations and the planar fit rotation was applied according to Wilczak *et al*. (2001). The storage flux was calculated following Aubinet *et al*. (2009). If the CO_2 concentration was not present, the storage flux was estimated to the discrete approach (Papale *et al*., 2006). The spikes detection was applied algorithm of double-difference time series, which is using outlier detection technique. To avoid nocturnal underestimation of CO_2 fluxes, the CO_2 flux data above u^* threshold 0.08 ms^{-1} were corrected (Fig. 3). The marginal distribution sample (MDS), which is advanced look-up table method was used to fill the gap in the data. The missing 30 minute NEE data were binned by meterological variable (air temperature and incoming radiation or net radiation) for a month.

2.4. Partition of Re and GPP

Net ecosystem exchange of CO_2 (NEE) was partitioned into photosynthetic (gross primary production, GPP) and respiration fluxes (ecosystem respiration, Re). That is, the difference between GPP and Re is NEE. After removal of the night-time CO_2 flux above u^* threshold, Re was estimated using the Q_{10} function according to LIoyd and Taylor (1994). The half-hourly data were aggregated to estimate daily values of NEE, GPP, and Re.

III. Results

3.1. Diurnal variation of CO_2 storage

The percentage of flux data retrieval was 71% during 2006 year at the apple orchard in South Korea. The planar fit rotation lead to systematic underestimation of the net ecosystem exchange of CO_2 (Fig. 1). Fig. 2 shows the diurnal variation in CO_2 storage (F_s) from 21st to 27th June. A positive value means storage of CO_2 below the eddy covariance measurement height, and a negative one indicates that CO_2 which is below the eddy covariance measurement height release into air layer. F_s was almost zero during the daytime because of turbulent mixing in the surface layer. F_s increased gradually after sunset, reached the daily maximum storage (about 0.35 mg CO_2 m^{-2} s^{-1}) just before sunrise, and then turned to release of CO_2 immediately after sunrise (Fig. 2).

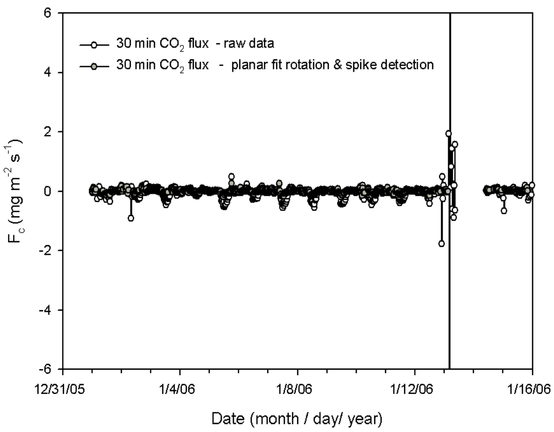

Fig. 1. Examples of spike detection and removal in CO_2 fluxes (F_c) observed at Uiseong apple orchard site in 2006. Cross with black line and empty circle mean raw CO_2 flux, black dot circle mean collected CO_2 flux with the spike removal.

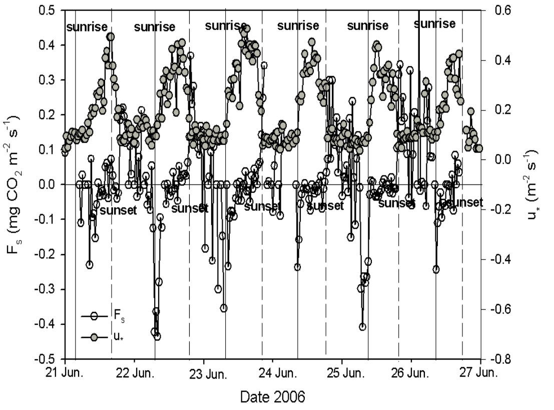

Fig. 2. Diurnal patterns of change in CO_2 storage (F_s), friction velocity (u^*) and from 21st to 27th June. Sunrise time is shown by the solid vertical lines, and sunset time by dashed vertical lines.

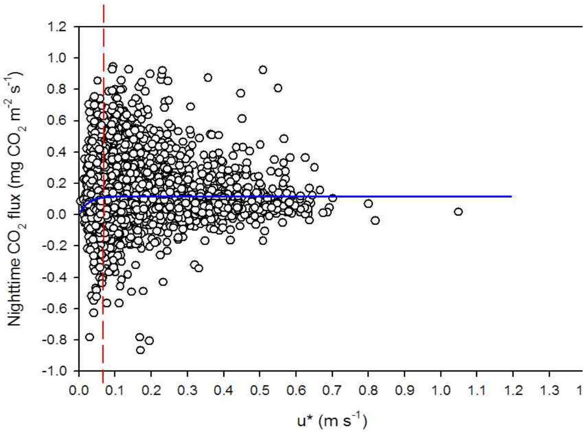

Fig. 3. Determination of the threshold friction velocity (u^*) from 1st January to 31st December 2006. The solid line represents a smoothed fraction fitted to the data. The dashed line represents the threshold below which the flux is lower.

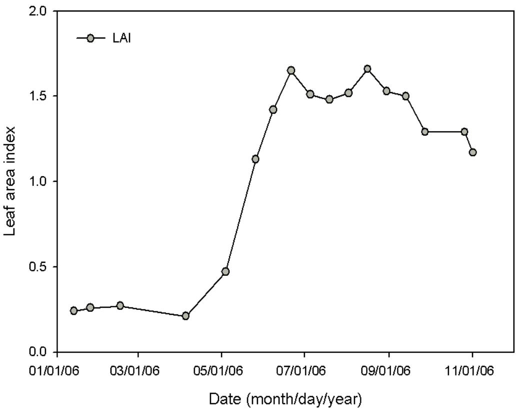

Fig. 4. Seasonal changes of leaf area index (LAI) at a Uiseong apple orchard. LAI of apple reached a maximum of 1.66 m^2 m^{-2} at the end of June.

3.2. Seasonal changes of CO_2 flux

Seasonal changes in the daily GPP, Re and NEE for the growing season were shown in Fig. 5. CO_2 uptake by 15 year apple trees started at 31st March. The daily GPP and NEE showed a rapid increase from early April with the growth of apple trees, and reached a maximum around 21st June, at the same time that Leaf Area Index (LAI) reached a maximum (Fig. 4). Large daily GPP exceeding 9 g C m^{-2} d^{-1} continued until 15th August, and then showed a steep decrease in the maturing stage (Fig. 5). The net ecosystem exchange (NEE) of apple orchard re-estimated as –398.5g C m^{-2} y^{-1} in 2006. The standardized FLUXNET protocol results in different of estimation of NEE (Kim *et al.*, 2012).

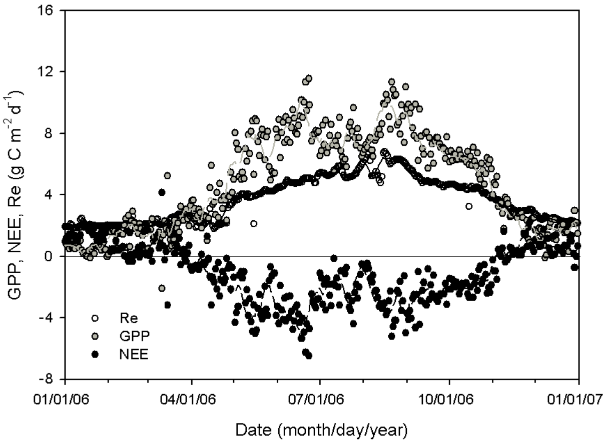

Fig. 5. Seasonal variation in daily GPP, Re, and NEE in 2006. Solid lines are 7 days running mean values. NEE was negative (CO_2 uptake) from April to late October and positive (CO_2 release) from November to the following March.

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References

Aubinet, M., C. Moureaux, B. Bodson, D. Dufranne, B. Heinesch, M. Suleau, F. Vancutsem, and A. Vilret, 2009: Carbon sequestration by a crop over a 4-year sugar beet/winter wheat/seed potato/winter wheat rotation cycle. *Agricultural and Forest Meteorology* **149**(3-4), 407–418.

Lloyd, J., and J. A. Taylor, 1994: On the temperature dependence of soil respiration. *Functional Ecology* **8**, 315-323.

Kim, G. Y., S. B. Lee, J. S. Lee, E. J. Choi, and J. H. Ryu, 2012: The Impact of air temperature during the growing season on NEE of the apple orchard. *Korean Journal of Soil Science and Fertilizer* **45**(6), 1211-1215.

Papale, D., M. Reichstein, M. Anbinet, E. Canfora, C. Bernhofer, W. Kutsch, B. Longdoz, S. Rambal, R. Valentini, T. Vesala, and D. Yakir, 2006: Towards a standardized processing of Net Ecosystem Exchange measured with eddy covariance technique: algorithms and uncertainty estimation. *Biogesciences* **3**, 571-583.

Webb, E. K., G. I. Pearman, and R. Leuning, 1980: Correction of flux measurements for density effects due to heat and water vapor transfer. *Quarterly Journal of the Royal Meteorology society* **106**(447), 85-100.

Wilczak, J. M., S. T. Oncley, and S. T. Stage, 2001: Sonic anemometer tilts correction algorithms. *Boundary-Layer Meteorology* **99**(1), 127–150.