Intercomparison of lower-cost and conventional eddy covariance systems for CO_2 and H_2O flux measurements above cropland monoculture and agroforestry

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1. Motivation

Short Rotation Alley Cropping (SRAC) agroforestry might represent a powerful nature-based solution to mitigate climate change, due to its increased carbon sequestration compared to monocropping (MC) agriculture. CO_2 and latent heat (LE) exchanges above SRAC can be studied via the eddy covariance (EC) technique, however SRAC represents a highly-heterogeneous landscape and the spatial representativity of EC is compromised. Lower-cost (LC) EC set-ups, tested in the last years with promising results [1,2,3], might provide a solution. Before widely employing LC-EC set-ups, they need to be tested against conventional EC.

2. Objectives

1) Intercompare CO_2 and LE fluxes from four LC-EC and one conventional EC above a MC cropland

2) Test if differences between LC-EC and conventional EC are smaller than differences between MC and SRAC

3. Material and methods

(a) Study site

The study site is in Wendhausen (Lower Saxony, DE). Mean annual temperature and precipitation are 9.9 °C and 618 mm. The agricultural land is divided in a MC area and a SRAC area. A map of the site is shown in **Fig. 1**. The dominant wind direction is southwest.

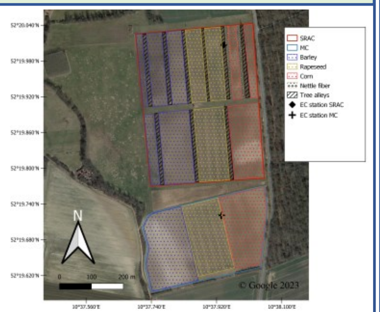

Fig. 1: Map of the experimental site, with land cover information and the location of the EC stations.

(b) Experimental set-up

In the MC, three LC-EC (LC-EC-I, LC-EC-II and LC-EC-III) and one conventional EC set-ups were installed. In the SRAC, one LC-EC set-up was installed. **Table 1** shows differences across set-ups. Each station was equipped with all the main meteorological sensors.

	f (Hz)	CO_2	H_2O	3D wind field	Flow rate ($L \cdot min^{-1}$)	Tube length (m)
LC-EC	2	GMP343 (Vaisala Oyj, Helsinki, FI)	HIH-4000 RH cell (Honeywell, Charlotte, USA)	Usonic-3 Omni (Metek GmbH, Elmshorn, DE)	2	3 (LC-EC-I) 3.5 (LC-EC-II) and 4 (LC-EC-III)
Conventional EC	20	Li-7200 (Licor Inc., Lincoln, USA)	Li-7200 (Licor Inc., Lincoln, USA)	Usonic-3 Omni (Metek GmbH, Elmshorn, DE)	15	1

Table 1: LC-EC and conventional EC set-ups.

(c) Flux computation and data analysis

- Pre-processing: (i) calculation of H_2O concentration from relative humidity (RH) following [3] and (ii) correction of CO_2 measurements for pressure, RH and temperature for the LC-EC; (iii) time lags estimation.
- Fluxes were calculated with EddyPro 7.0.9 and filtered according to standard quality checks.
- Post-processing: statistical comparison between set-ups and analysis of flux differences according to turbulence characteristics.

4. Results and discussion

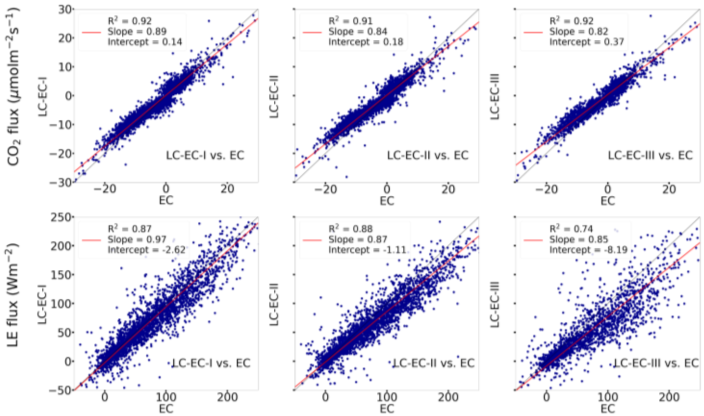

Fig. 2: Comparison of lower-cost EC (y-axis) against EC (x-axis) for CO_2 (top row) and LE (bottom row) at the MC site.

- 1:1 plots show a good agreement of LC and conventional EC (**Fig.2**), with slopes ranging from 0.82 to 0.89 and R^2 above 0.9 in the case of CO_2, and from 0.85 to 0.97, with R^2 of 0.74 to 0.88, in the case of LE.

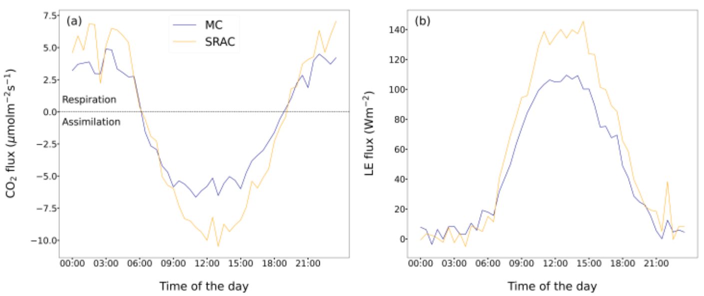

Fig. 3: Diel cycles of MC and SRAC, for (a) CO_2 and (b) LE fluxes. The diel cycle in the MC was calculated as the average of all three LC-EC set-ups.

- Diel cycle of the CO2 flux (Fig. 3a) shows enhanced C sequestration during daytime and C respiration during nighttime over SRACS compared to MC, due to increased photosynthetic C uptake and increased stomatal respiration above the SRACS.
- LE diel cycle (Fig. 3 b) show higher LE fluxes during daytime and similar LE fluxes during the night above SRACS compared to MC, due to enhanced physiological activity of the trees.

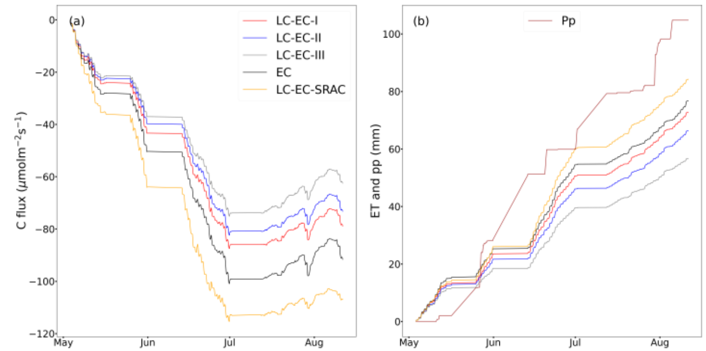

Fig. 4: Cumulative sums of C and ET fluxes for all four set-ups in the MC and SRAC across the measurement campaign (March to August 2022). Precipitation is plotted together with ET for reference.

- In accordance with the 1:1 plots, the different LC-EC in the MC underestimate the conventional EC cumulative sums at different rates (**Fig.4**).
- For CO_2, differences in cumulative sums across LC-EC set-ups in the MC are smaller than differences between SRAC and MC. The difference between LC-EC and conventional EC in the MC is around 50% to the difference between MC and SRAC.
- For ET, the differences between SRAC and MC are of the same order as the difference between LC-EC and conventional EC in the MC.

5. Conclusions

- LC-EC setups perform well compared to conventional EC, in agreement with the results from [1] and [2]. All LC-EC set-ups reproduce the ecosystem dynamics and are capable of detecting ecosystem differences (**Obj. 1**).
- The variability across LC-EC set-ups in the MC is smaller than the variability across SRAC and MC (**Obj. 2**).
- The LC-EC set-ups could be applied to address the spatial replication problem in EC, but more investigation is needed on the corrections during data analysis.
- The SRAC presents an enhanced C sequestration compared to the MC throughout the campaign, due to the much higher photosynthetic activity during daytime in the growing season.
- The SRAC increases ET, however a more detailed calculation is needed to address how the water use efficiency changes across both land uses.

References

[1] Cunliffe, A. M., Boschetti, F., Clement, R., Sitch, S., et al. (2022). Strong correspondence in evapotranspiration and carbon dioxide fluxes between different eddy covariance systems enables quantification of landscape heterogeneity in dryland fluxes. *J. Geophys.: Biogeosciences*, 127, e2021JG006240. 10.1029/2021JG006240

[2] Hill, T., Chocholek, M. and Clement, R. (2017), The case for increasing the statistical power of eddy covariance ecosystem studies: why, where and how?. *Glob. Change Biol.*, 23: 2154-2165. 10.1111/gcb.13547

[3] Markwitz, C and Siebicke, L. (2019). Low-cost eddy covariance: a case study of evapotranspiration over agroforestry in Germany. Atmos. Meas. Tech., 12: 4677-4696. 10.5194/amt-12-4677-2019

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