The carbon budget of a winter wheat field: An eddy covariance analysis of seasonal and inter-annual variability

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Motivation

Arable land occupies large areas of the global land surface and hence plays an important role in the terrestrial carbon cycle. Therefore agro-ecosystems show a high potential of mitigating greenhouse gas emissions while optimizing agricultural management. Consequently, there is a growing interest in understanding carbon fluxes from arable land as affected by regional environmental and climate influences as well as management conditions.

Objective

The overall aim was to analyze seasonal patterns and inter-annual differences of carbon exchange during a two year observation period (Oct. 2007 to Oct. 2009) on a winter wheat field . Specific aims were:

(i) to derive a consistent 2 year data set of daily carbon fluxes based on Eddy covariance (EC) measurements
(ii) to compare the differences in seasonality of carbon fluxes and carbon balances
(iii) to identify the impact of meteorology and agricultural management on measured carbon fluxes

Methods

During the period under study various continuous or at least bi-weekly measurements were carried out:

(i) Eddy covariance measurements
(ii) Meteorological measurements
(iii) Soil measurements
(iv) Biometric measurements

Processing of (EC) carbon fluxes

(i) Standard flux corrections (planar fit, Schotanus, Moore, Webb...)
(ii) Strict quality control (Mauder & Foken, 2004)
(iii) Footprint filter (Korman & Meixner, 2001)
(iv) Combined flux partitioning / gap filling method
(v) Uncertainty estimates (Richardson & Hollinger, 2007)

Site description

Field size: 6.58 ha / fetch: 90 to 135 m
Climate: temperate maritim (9.9°C, 698 mm)
Soil: Luvisol / silt loam

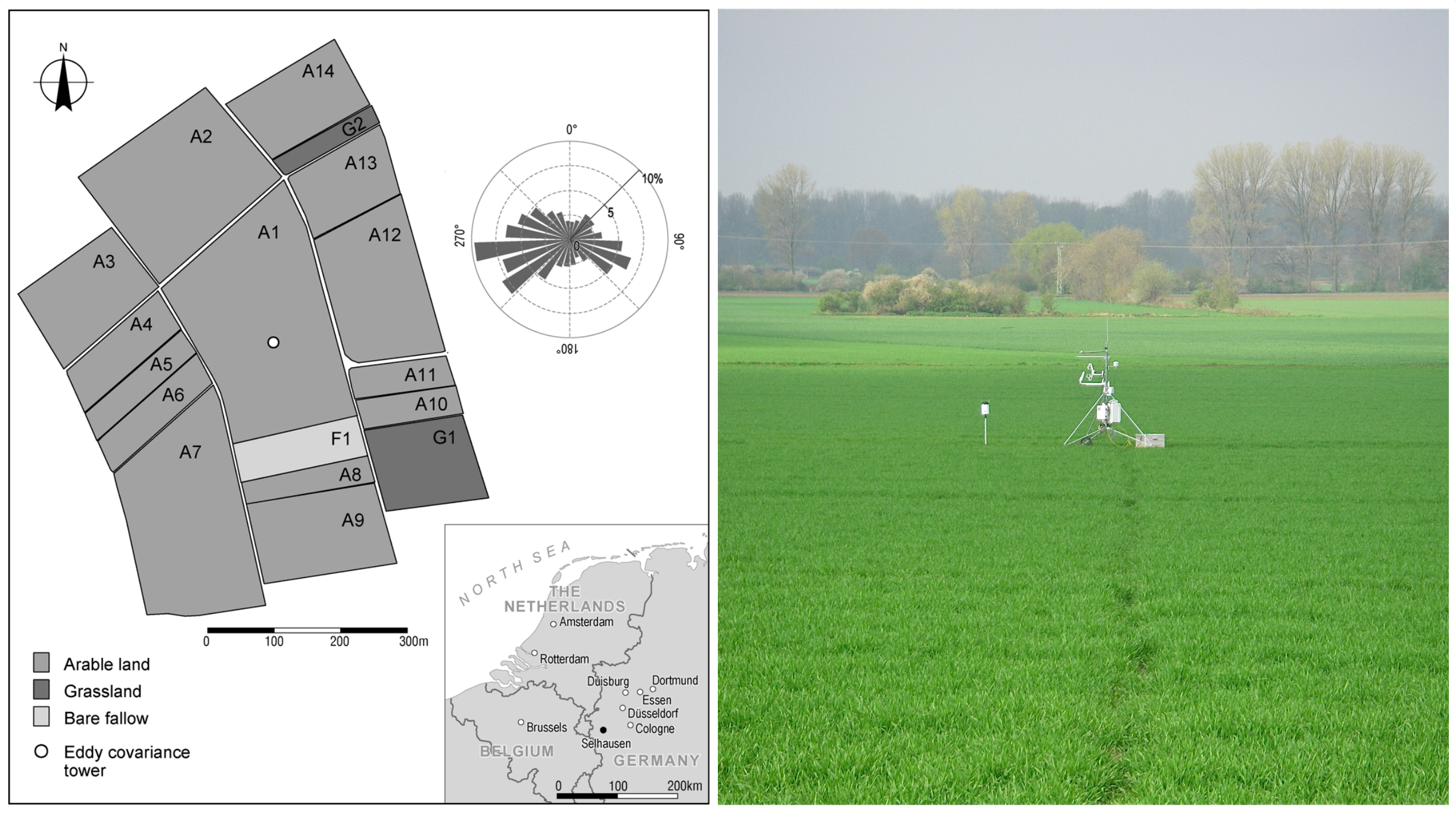

Fig. 1: Location of the Selhausen test site (winter wheat field in the center) and map of the surrounding agricultural fields (left panel) and fotograph (right panel) of the Eddy Covariance tower in the winter wheat field (April 2008).

Results

Tab. 1: Annual statistics of air and soil temperature, photon flux density (PPFD), precipitation, daytime vapor pressure deficit (VPD) and soil water content (SWC) at the test site.

Variable	1st year	2nd year
Air temperature (°C)	10.5	10.2
Soil temperature (°C)	10.4	10.5
PPFD (µmol m^{-2} s^{-1})	261	268
daytime VPD (kPa)	0.5	0.57
SWC at -0.1 m (m^3 m^{-3})	31.7	30.5
SWC at -0.3 m (m^3 m^{-3})	30.8	32.6
Precipitation (mm)	768	700

- Same annual **NEE** in in both years
- **GPP** was higher by 220 g C m^2 in the 1st year
- **R_{eco}** was higher by 220 g C m^2 in the 1st year (sugar beet residues)
- Max. carbon uptake rates of up to 19 g C m^{-2} d^{-1} between May and June
- Max. carbon release (R_{eco}) of up to 13 g C m^{-2} d^{-1} in June 2008 and 8 g C m^{-2} d^{-1} in June 2009
- Most remarkable management effects were a) an increase of up to 5 g C m^{-2} d^{-1} in R_{eco} for up to 7 days after fertilization and b) an increase of R_{eco} of approx. 1 g C m^{-2} d^{-1} for a period of 5 to 6 days after ploughing
- The period from sowing to harvesting was 23 days shorter in the 1st year
- Complete transformation from green to brown leaves occurred approx. 2 weeks earlier in the second year as compared to the 1st year
- By taking into account the carbon losses due to removal of biomass during harvest, the winter wheat field acts as a carbon source with respective **net biome productivities** of 246 and 201 g C m^2 a^1

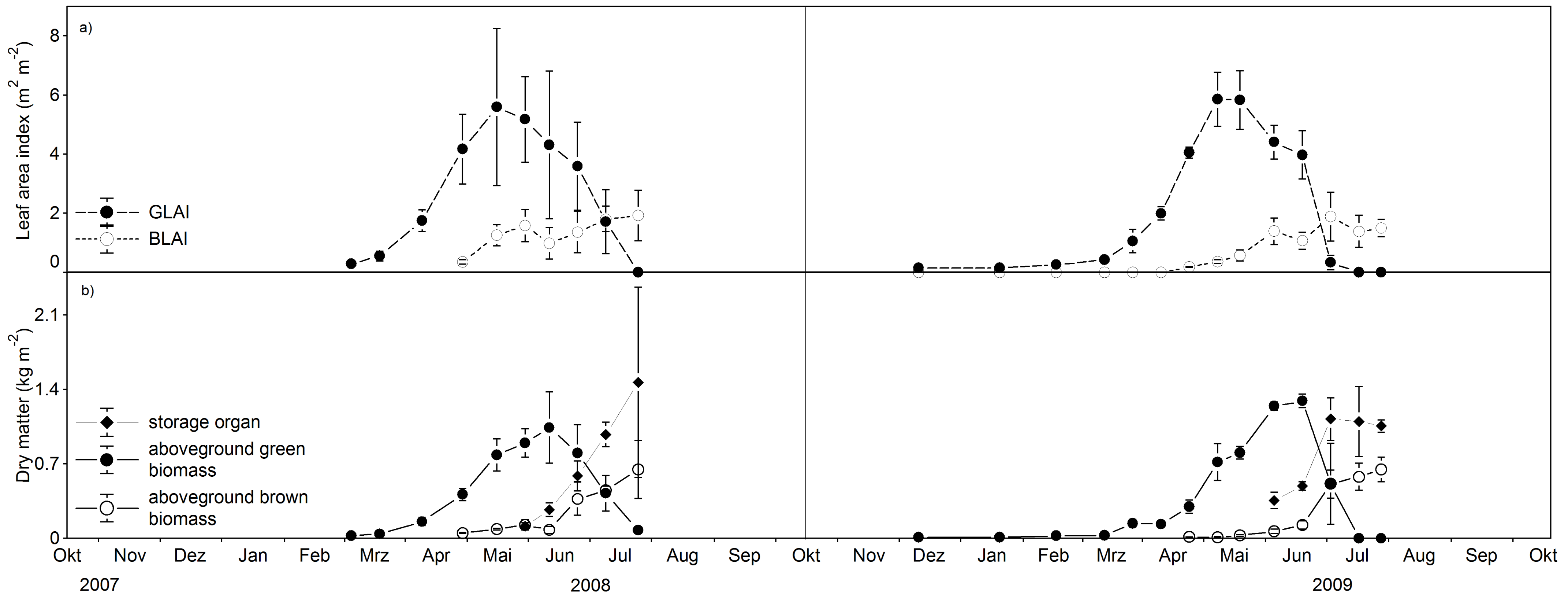

Fig. 2: Evolution of vegetation parameters for winter wheat at the Selhausen test site.

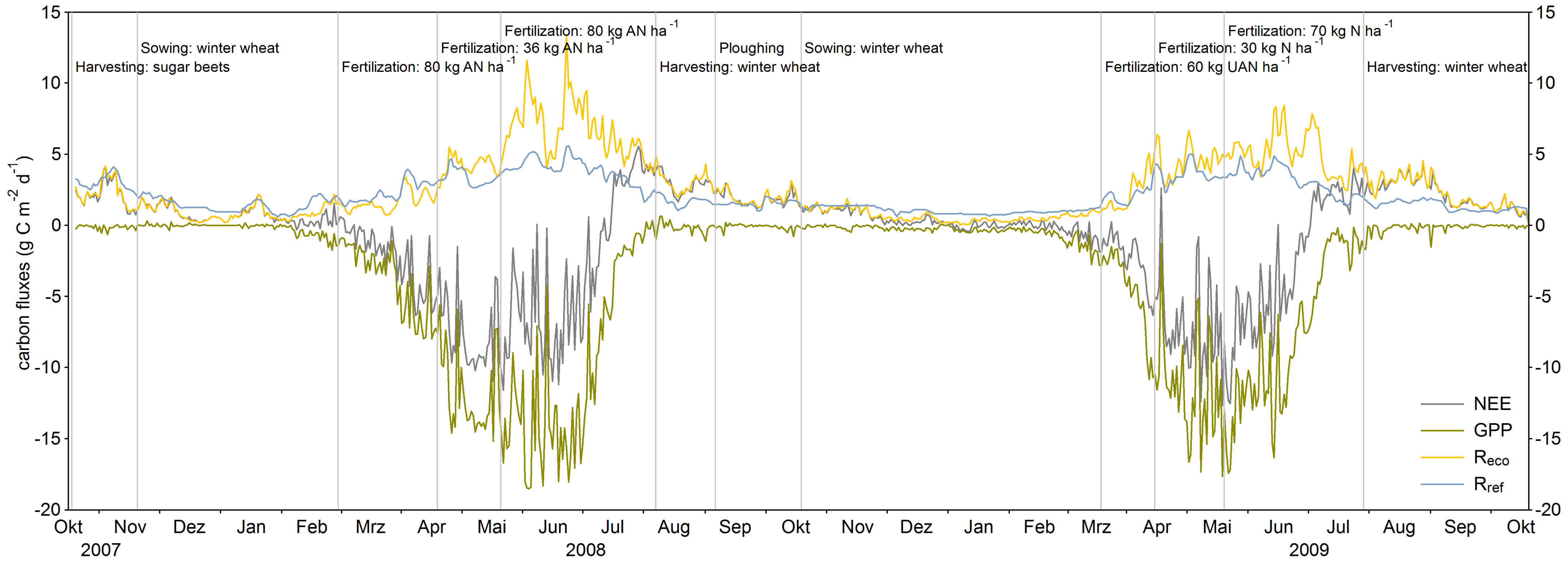

Fig. 3: Daily integrated net ecosystem exchange (NEE), gross primary productivity (GPP), ecosystem respiration (R_{eco}) and ecosystem respiration at a reference temperature of 10◦C (R_{ref}). Vertical lines indicate important management activities.

Table x: Estimated annual net ecosystem exchange of CO_2 (NEE), gross primary production (GPP) and ecosystem respiration (R_{eco}) from two adjacent years of winter wheat starting from 19 Oct 2007 and 2008, respectively.

g C m^{-2} a^{-1}	first year	second year
NEE	-270 (±19)	-270 (±18)
GPP	-1350 (±18)	-1131 (±30)
R_{eco}	1081 (±31)	861 (±43)

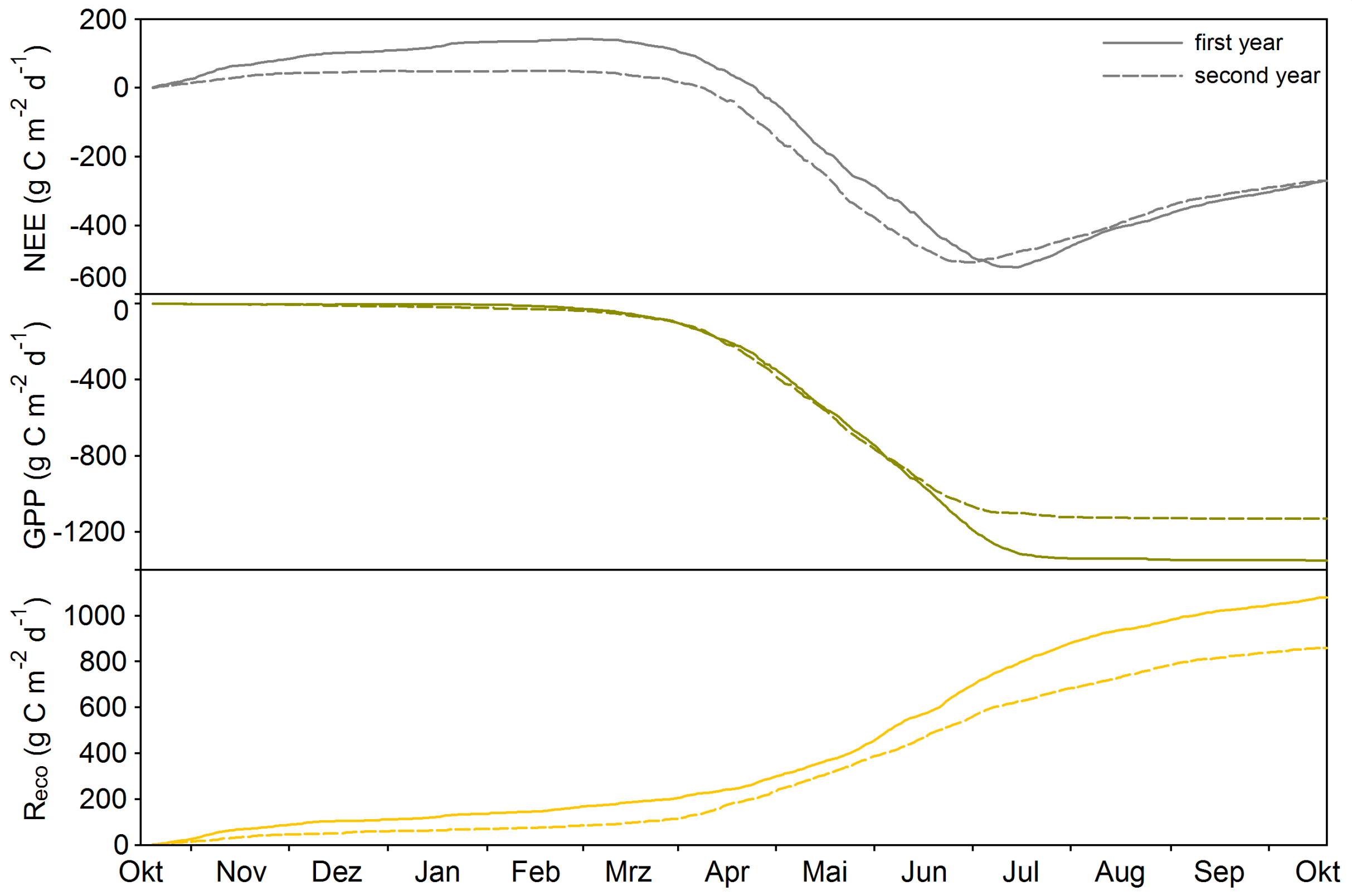

Fig. 4: Comparison of cumulative net ecosystem exchange (NEE), cumulative gross primary productivity (GPP) and cumulative ecosystem respiration (R_{eco}) for the two observed years.

Conclusions

(i) Almost same values of NEE and its uncertainty for years with different management dates and differences in meteorological conditions
(ii) Main difference in the annual GPP budgets between both years was the result of the longer biological activity of the winter wheat canopy in first year
(iii) The longer biological activity in the first year was compensated by the more intensive heterotrophic respiration (sugar beet residues) in the beginning of that year
(iv) Taking into account the amount of carbon removed from the field during harvest, the winter wheat field was found to be a carbon source to the atmosphere in both years (net biome productivity: 246 and 201 g C m^{-2} in 1st year and 2nd year, respectively)

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