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Monitoring cropland daily carbon dioxide exchange at field scales with Sentinel-2 satellite imagery

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C flux dyamics at Heydenhof

GPP and Reco dynamics almost synchronously complemented each other (as has been observed as well by Béziat et al. (2009), with Reco fluxes of 80% and 72% of GPP in the first and second WW growing period (sowing to harvest), respectively. These proportions were higher than what had been observed by Aubinet et al. (2009) who measured values of 60% for Reco/GPP for two WW growing periods but very similar to the values of Béziat et al. (2009) of 80%. This could be explained by e.g. relatively higher heterotrophic respiration due to a higher SOC content at our site, different climatic conditions, or different WW varieties. However, these hypotheses could not be verified because not all of the necessary data were available in detail.

During the growing season of WR, GPP peaked on 28 June 2020 with -16.23 g C m^{-2} d^{-1} after the typical decrease during flowering (Itzerott and Kaden, 2006) from around 23 April 2020 to around 31 May 2020 (Figure 2 in main manuscript). The peak in GPP matched well with a respective rapeseed value of -15.4 g C m^{-2} d^{-1} for the French site Auradé (Béziat et al., 2009). Reco showed the highest efflux on 27 June 2020 of 11.48 g C m^{-2} d^{-1} after a steady increase, coinciding with a second GPP peak, before declining until harvest. The GPP peak might have happened in response to an intense rain event, replenishing soil moisture after a relatively dry growing season. However, Reco did not show a similar response as could have been expected. Our maximum value for Reco was slightly higher than the reported value from Auradé, being only 8 g C m^{-2} d^{-1} (Béziat et al., 2009). The course of NEE indicated net C uptake by the ecosystem from the start of the flux measurements until shortly before harvest of WR, followed by the ecosystem turning into a source of C until the beginning of March 2021. Max net C uptake of WR occurred on 20 June 2020 with a value of -9.75 g C m^{-2} d^{-1}.

After harvest of WR and before sowing of WW (2020/2021), absolute values of GPP and NEE increased two times due to re-growth interrupted by shallow soil cultivation events. Reco increased after harvest until it declined towards the cold season but showed no response to the soil cultivation events. The peak of the first re-growth turned the ecosystem from a source close to net-zero exchange.

All three fluxes showed a stronger dynamic in the second growing season (WW 2020/2021). Absolute values of GPP, and Reco peaked at -24.68 and 14.85 g C m^{-2} d^{-1}, respectively, on 18 June 2021, being the warmest day of that summer with 26.2°C. Net C uptake increased up to -13.66 g C m^{-2} d^{-1} on 02 June 2021. Absolute maximum values of GPP and Reco were both relatively high as compared to the values reported for other WW sites, ranging

from -15 to -18.9 g C m^{-2} d^{-1} for GPP and 3.1 to 11.5 g C m^{-2} d^{-1} for Reco in France and Belgium (Béziat et al., 2009; Aubinet et al., 2009). However, crop variety, local climate and biogeochemical factors leading to a max GPP and Reco can vary tremendously and detailed analyses would be necessary to evaluate and explain absolute differences. Still, these results seemed reasonable since our max Reco value was measured on an extraordinary hot summer day, on a fairly moist soil with a soil organic C content of 1.5-2%.

Post-harvest re-growth was less expressed after WW but soil grubbing on 07 September 2021 caused absolute values of GPP to decline. A short-term C flush from increased heterotrophic respiration due to soil disturbance and possibly residue incorporation led to a remarkable short increase in net C loss from the ecosystem. While that increase quickly leveled off, the system remained a net source of C. These C dynamics of post-harvest re-growth phases had also been observed by (Béziat et al., 2009) for two French cropland sites.

The third cropping season, WW2, (2021/2022) was characterized by a 1-month shorter growing season (sowing to harvest) and only about 70% of precipitation of WW1. Both, WW1 and WW2 remained a distinct source of CO_2 until mid of March. GPP and Reco were both lower than in WW1, peaking at -18.46 and 11.16 g C m^{-2} d^{-1} on days 15 May 2022 and 24 June 2022 respectively. They were just within the respective values reported for French and Belgian WW sites. Maximum net C uptake of -11 g C m^{-2} d^{-1} occurred on 18 May 2022. Absolute values of NEE and GPP peaked almost one month earlier than in WW1.

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