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ORIGINAL PAPER

SEASONAL CARBON EXCHANGE IN ORGANIC AND CONVENTIONAL LEY AND WINTER WHEAT AGROECOSYSTEMS IN CENTRAL LITHUANIA

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Abstract

Due to the increase in anthropogenic CO_2 emissions in the atmosphere, the choice of technologies for mitigating climate change is becoming an important challenge for the agricultural sector. The investigation of two farming types, i.e. organic (OF) and conventional (CF), and their environmental impact on the carbon budget in ley (grass-clover) (G) and winter wheat (W) agroecosystems was carried out in 2014 - 2015 at the Training Farm of the Aleksandras Stulginskis University. For the estimation of carbon exchange, the closed chamber method with a portable measurement system was used. Compared with CF, OF reduced the mean soil respiration by 12% (p = 0.31) and 13% (p = 0.55); however, the total respiration Ra+s (autotrophs + soil) was reduced by only 2% and 15% in the ley and wheat agroecosystems, respectively. The strong positive correlation between soil respiration and temperature (r = 0.8, p = 0.25), moisture content (r = -0.7, p = 0.04), and electrical conductivity (r = 0.3, p = 0.47) confirmed the impact of soil physical properties on CO_2 emissions from soil to the atmosphere. The CO_2 sequestration potential of crops or gross primary production (GPP) also correlated with air temperature (r = 0.7), precipitation (r = -0.5) and leaf area index – LAI (r = 0.7). The amount of CO_2 captured from the atmosphere was higher than that emitted during respiration in both the ley and wheat agroecosystems. The net ecosystem production (NEP) of 11.48 and 11.58 µmol $m^{-2}s^{-1}$ of the OF and CF ley was higher than the 8.93 and 9.42 µmol $m^{-2}s^{-1}$ of the OF and CF wheat, respectively. Given the Rs+a and CO_2 sequestered in the biomass data, the difference between the carbon exchange for the OF and CF agroecosystems was insignificant. Therefore, the crop might be a more important CO_2 sequestration factor than the farming type in planned rotation. Specifically, ley is preferred over winter wheat (irrespective of the farming system) for curbing the atmospheric C in biomass in terms of ecology. Nonetheless, the preference also depends on a farm's practical purposes.

Keywords: CO_2 emissions, farming systems, gross primary production (GPP), net ecosystem production (NEP), environment.

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INTRODUCTION

In terms of solving human-induced environmental problems, climate change mitigation remains the most relevant approach in a situation where the greenhouse gas (GHG) concentration (mainly CO_2) has increased by 70% since 1970 (Smith et al. 2003). Croplands represent approximately 12% of the Earth's surface (Wood et al. 2000) and one-third of the land surface in Europe, and therefore their importance for climate change is evident. Plants and soils in agroecosystems are actively involved in the formation of climate, significantly assimilating and accumulating a high carbon pool in their biomass. Currently, agriculture produces 12-15% (9% in the EU) or 5.1-6.1 Gt CO_2–eq. yr^{-1} of total anthropogenic GHG emissions (Smith et al. 2010).

Permanent carbon exchange between the atmosphere and biosphere in ecosystems is achieved by two opposing processes, i.e. CO_2 emissions through the process of respiration by organisms and CO_2 sequestration in biomass during photosynthesis (Smith et al. 2003). Although soil CO_2 emissions comprise the largest (60-90%) part of the global C-cycle (Kauer et al. 2015), also meteorological parameters, especially temperature, strongly influence carbon exchange (Raich, Tufekcioglu 2000, Ciais et al. 2010, Aertsens et al. 2013).

The determination and application of sustainable agricultural technologies (organic, etc.) remain an important measure aimed at climate change mitigation in the soil–plant–atmosphere system. Therefore, sustainable agricultural systems with reduced emissions of greenhouse gases have become an important issue worldwide (Taylor et al. 2013).

Agroecosystems are the prevailing type of ecosystems, covering 53.1% of Lithuania's territory and generating 4.945 10^{-3} Gt or 23.4% of CO_2 emissions produced by all Lithuanian economic entities (FAO, 2013). However, previous studies have focused only on soil carbon emissions (Baležentienė, Kusta 2012); thus, precise and detailed data on carbon budgets in agroecosystems of organic and conventional farming at the regional level are lacking. Therefore, an assessment of how agritechnological and environmental conditions influence the C cycle could be an important step in shifting C exchange towards reduced CO_2 emissions, predicting changes in agroecosystems and supporting environmental sustainability when choosing land-use types and management practices.

The main objective of this study was to evaluate the impact of organic and conventional farming on the net ecosystem productivity in ley and winter wheat agroecosystems by means of quantifying the impact of meteorological (temperature and precipitation) and soil conditions (temperature, humidity, and electric conductivity).

MATERIAL AND METHODS

The investigation of the environmental impact on carbon accumulation in biomass and its budget in ley (temporary grasslands, G) and winter wheat (W) agroecosystems of different farming systems (FS), specifically organic (OF) and conventional farming (CF), was performed during the plant vegetation season in 2014 and in 2015 at the Training Farm of the Aleksandras Stulginskis University (54°52'N, 23°49'E), central Lithuania. The organic farm superseded the conventional farm in 1996 and has since been maintained at the Training Farm. OF has been certified by the EKOAGROS (Lithuanian Committee for Organic Agriculture).

Lithuania lies in the cold temperate zone (5-6), with moderately warm summers and medium cold winters (Baležentienė, Kusta 2012). The average temperature in July is approximately 17°C, and in winter it falls to approximately -5°C; the interval between the mean summer and winter temperatures is approximately 20°C.

The cropland soil types were *Luvisols*: *Hapli-Epihypogleyic Luvisol*, *LVg-p-w-ha* in the OF and CF grassland fields and *Albi-Epihypogleyic Luvisol*, *LVg-p-w-ab* in the OF and CF wheat fields.

Assessments of the CO_2 emissions and C exchange were carried out in differently managed organic (OF) and conventional (CF) agroecosystems of ley (short-term grasslands, G) and winter wheat (W) – Table 1. A perennial

Table 1

Fertilization and technological parameters in the agroecosystem

Specification	Conventional farming (CF)	Organic farming (OF)
Winter wheat (W) field (ha)	13.7	23.41
Ley (G) field (ha)	22.86	12.48
Mineral fertilization	NPK 8-20-30, 200 kg ha^{-1} additionally ammonium nitrate, 150 kg ha^{-1} (52 N kg ha^{-1})	-
Manure	100 t ha^{-1} in autumn after lay II yr.	36 t ha^{-1}
Crop rotation	ley-ley + winter wheat + maize + barley+spring rapseed+ winter wheat + spring barley mixture with peas undersown with ley	ley – ley – winter wheat – oats-peas mixture undersown with ley

grass mixture composed of 50% red clover (*Trifolium pratense*) 'Start' and 50% timothy (*Phleum pratense)* 'Jumis' and undersown to oats 'KWS Contender' (170 kg ha^{-1}) and peas (*Pisum sativum*) 'Kiblukai' (50 kg ha^{-1}) was used as cover crops in 2013 (sown on 07 May). A 2-cut system was applied in the ley in 2014 (06.04 and 08.11) and 2015 (06.02 and 08.06).

Measurements and analyses of bio-parameters were performed every 7-10 days depending on the meteorological conditions. The measurement sites (a) were set out randomly every 50 - 100 m in linear transects, oriented along the N-S direction in the fields. The measurement sites were set out at a minimum distance of 20 - 25 m from the field edge to avoid the margin effect. The measurement plots (b) in 6 replications were installed in each site.

The net ecosystem carbon exchange was considered as the total rate of organic carbon accumulation or net ecosystem production (NEP). For the estimation of the NEP in OF and CF ley and wheat ecosystems, the soil respiration (R_s) in daytime and autotrophic respiration (R_a) in the night-time were measured using the closed chamber method (Smith et al. 2003) with a portable measurement system (LCpro, ADC Bioscientific LTD, UK). Additionally, the photosynthetically assimilated CO_2 in crop biomass or CO_2 gross primary production (GPP, μmol $m^{-2}s^{-1}$) were measured for each agroecosystem. The C exchange was specified as the net ecosystem production, i.e. the difference between gross primary production (GPP) and ecosystem respiration (R_{a+s}), and described by the equation: NEP= GPP-R_{a+s} (Smith et al. 2003, Ciais et al. 2010).

To evaluate crop photosynthetic surface, the crop density (un. m^{-2}) was measured on 0.25 m^{-2} (0.5 m x 0.5 m) plots in 6 replications. The leaf surface area from these plots was scanned using a WinDias 3 device, and leaf area index (LAI, m^2 m^{-2}) was calculated.

To evaluate the impact of physical parameters on CO_2 emissions, the following soil parameters: temperature (T_s, °C), humidity (M, %) and electrical conductivity (EC, mS cm^{-1}), were determined at 10 cm depth by an integrated sensor (HH2 AT Delta-T Devices Ltd, WET-2).

Composite soil samples were taken using a cylindrical auger in each field. Soil agrochemical analyses (ISO10381-2: 2002) were carried out in the Agrochemical Research Laboratory of the Lithuanian Agriculture and Forestry Research Centre. The content of the following parameters was evaluated: organic C_{org} and total carbon C_t, total nitrogen N_t, C/N, pH, P_2O_5, K_2O and electrical conductivity EC (Table 2). These characteristics were similar in both farming systems. However, the CF soils were superior to the OF with

Table 2

Soil agrochemical parameters

Farming	Agro-eco-system	Acro-nym	C_{org} (%)	C_t (%)	N_t (%)	C/N	pH	P_2O_5 (mg kg^{-1})	K_2O (mg kg^{-1})	EC (mS cm^{-1})
OF	ley	OFG	1.62	1.67	0.174	9.6	7.0	175	138	97.8
	winter wheat	OFW	1.69	1.76	0.18	9.8	7.1	400	179	116
CF	ley	CFG	2.10	2.16	0.194	11.1	6.9	314	153	126
	winter wheat	CFW	1.60	1.79	0.161	11.1	7.4	199	153	146

a higher C/N ratio, which indicated a higher C supply. Nonetheless, the determined low C/N ratio (9.6-11.1) indicated the occurrence of intensive mineralization and humification processes leading to the formation of fertile soils in both the OF and CF fields.

The higher C/N ratio of 11.1 in the CF than in the OF soils had been induced by both the environmental conditions (different soil M and T_s) and the applied intensive agricultural technologies. Furthermore, the C/N ratio increased as a result of applying mineral fertilizers in CF soils (Table 2).

Meteorological conditions. The suitability of a season for plant growth is expressed as a ratio of humidity and temperature, or the hydrothermal coefficient (HTK).

The 2014 March HTK = 1.83 shows the amount of moisture, and in the HTK April the same years equal 0.78 shows that conditions were too dry for plant growth, twice as dry as in March. The HTK in the subsequent months was: May = 2.03, June = 1.13, July = 0.82, August = 2.02, and September = 1.98 (Figure 1). The HTK in October = 1.61 corresponded to nearly optimal

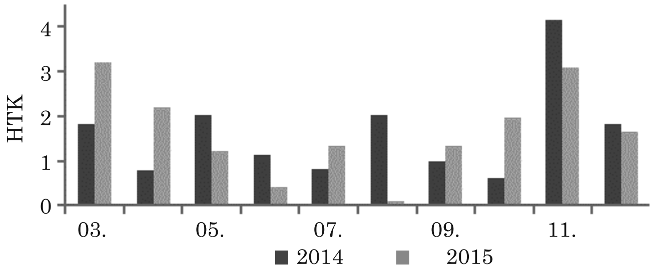

Fig. 1. Hydrothermal coefficient

humidity, while in November HTK = 4.15, indicating three-fold more moisture than in October.

The 2015 growing season was warmer but drier in comparison with 2014. This is confirmed by the mean hydrothermal coefficient (HTK), which was 1.81 in 2014 and 1.47 in 2015. These fluctuations and differences in the weather conditions could have affected not only the abiotic parameters of the agroecosystem but also the photosynthesis and respiration processes.

Statistical data analysis. For the quantitative evaluation of data, Student's *t* test was used to compare the organic and conventional agroecosystems and to verify whether there were any statistically significant differences between the data. ANOVA and multiple regression models were used to evaluate the interaction between the environment, biometric parameters and CO_2 emissions. Data were considered statistically significant at the probability level of $p < 0.05$.

RESULTS AND DISCUSSION

The soil seasonal CO_2 emissions (R_s) significantly depended on the seasonal environmental conditions that impacted the various lifecycle processes of the crops and soil biota (Figure 1). T_s ranged between 4.6 and 25.8°C (p = 0.59) irrespective of the farming type and crop species (Figure 2a).

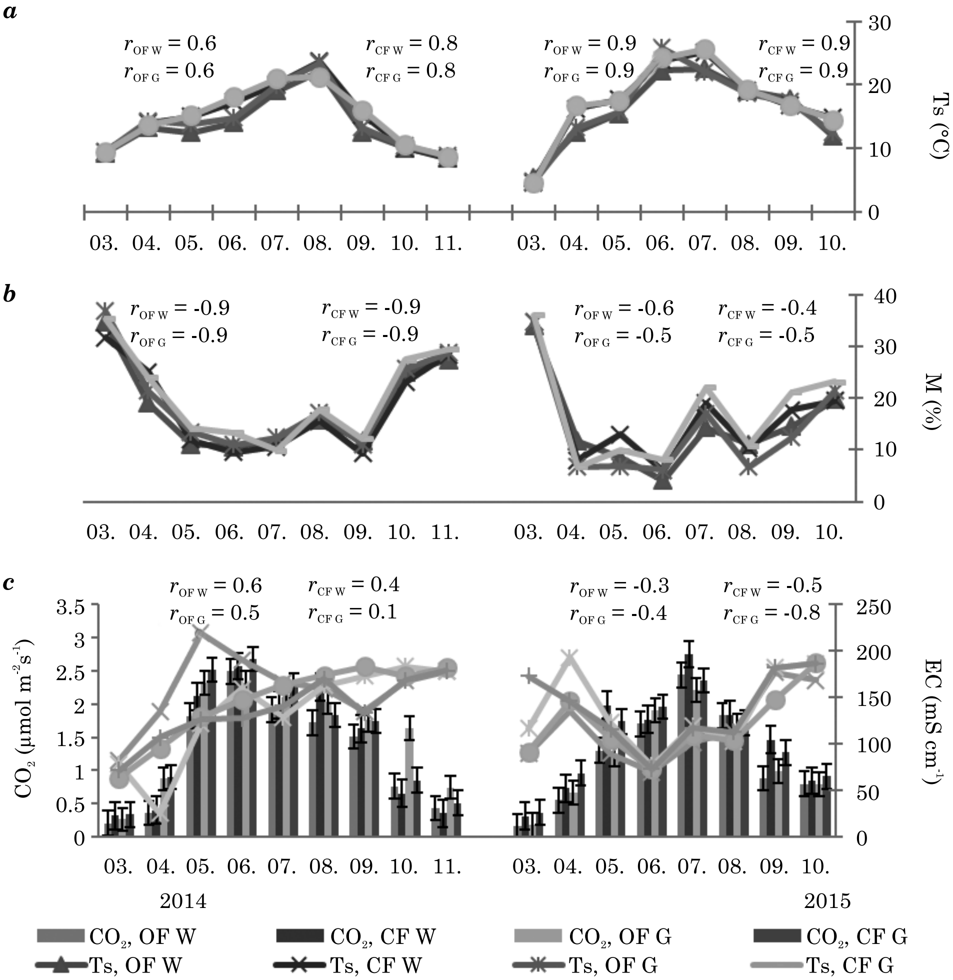

Fig. 2. Correlations between soil respiration and temperature (*a*), moisture content (*b*), and electrical conductivity (*c*) in the agroecosystems

Slightly higher Ts in CF crops induced more intensive processes of the soil biota and resulted in an average of 12% higher R_s emissions than in OF agroecosystems. Strong correlations between the mean R_s (r = 0.7, p = 0.47) and T_s (r = 0.8, 0.50) were found in all of the tested crops and farming types.

Soil moisture M depended on precipitation and was strongly negatively correlated with R_s (r = -0.6 and r = -0.7). This is consistent with the previous conclusions (Schimel et al. 2000). However, the response of R_s to M is complex, as R_s is restricted in the case of low and high soil moisture content, and the response rate may also be confounded by soil temperature (Zhang et al. 2016). Soil moisture surplus during autumn and spring leads to anaerobic conditions, which are unfavourable for the soil biota and plant roots in our temperate climate. Therefore, R_s decreased with decreasing T_s and M, generally in autumn. Furthermore, there was a stronger positive M effect on R_s alterations (r = 0.8, $p < 0.05$) in the summer period (June-Sept.) than during the cooler autumn and spring periods (r = 0.2) – Figure 2*b*. Numerous researchers (Borken et al. 2003, Lee et al. 2004, Flechard et al. 2007, Jassal et al 2009, Chen et al. 2014) explained the correlation between positive T_s and M not only by their direct effects on the soil physical properties but also by the increased biological activity of the soil.

Soil EC mostly depended on the soil's physical and chemical properties (Samouelian et al. 2003). Dissolved ions affect both the behaviour of soil biota (Macek et al. 2005) and Rs emissions. In our case, Rs also changed along with the crops being subjected to M (OF W r = 0.2, CF W r = 0.1, OF G r = 0.1, CF G r = 0.1) and T_s (r = 0.2). EC was smaller by 20% and 29% (in 2014) and 13% and 15% (in 2015) in CF W and G than in OF crops, possibly due to the variance of M and the ion concentration of mineral fertilizers in soil solution. A smaller EC and its negative correlation with R_s were quantified in OF W (137.5 mS cm^{-1}, r = -0.3) and OF G (138.4 mS cm^{-1}, r = -0.4) in the warmer and drier 2015. Although EC increased during the plant growing period independent of the fertilizer amount, its mean values were similar in the assessed agroecosystems, representing sufficient ion amounts in the soil solution and thus favourable conditions for the plant and soil biota.

The mean R_s was lower by 9% and 18% (p = 1.62) of OF W and by 10% and 14% (p = 1.47) of OF G than of CF crops in 2014 and 2015, respectively. Consistent with former research (Aertsens et al. 2013, Kauer et al. 2015), a higher R_s was estimated in OF crops, thus indicating more favourable environmental conditions, which are formed and maintained by different crop management techniques, for the soil biota and physiological processes in the plant root than within CF. Although R_s emissions differed between the assessed agroecosystems, they can be controlled by optimizing or selecting sustainable agro-technologies and crop species.

The data revealed that plant respiration R_a contributed CO_2 to the biosphere and the contribution varied across the farming types and was also dependent on the environment and the plant LAI in the analysed agroecosystems (Table 3).

Crop respiration (R_a) ranged between 0.067 and 2.995±0.19 μmol $m^{-2}s^{-1}$ and composed an insignificant ratio of agroecosystem emissions. R_a increased until June-August due to the rising T (r = 0.6-0.7), favourable M (r = - 0.5 - 0.6)

Table 3

Autotrophic respiration (R_a) in agroecosystems (p < 0.05, mean ± SE)

Month	FS	R_a, CO_2 (µmol $m^{-2}s^{-1}$)					
		G			W		
		2014	2015	mean	2014	2015	mean
03.	OF	0.287±0.14	0.075±0.14	0.181±0.1	0.241±0.21	0.067±0.24	0.154±0.3
	CF	0.314±0.19	0.088±0.21	0.201±0.2	0.283±0.24	0.098±0.17	0.191±0.2
04.	OF	0.831±0.16	0.174±0.12	0.503±0.2	0.674±0.18	0.387±0.19	0.531±0.2
	CF	0.903±0.24	0.287±0.28	0.595±0.3	0.841±0.16	0.394±0.21	0.618±0.1
05.	OF	2.237±0.23	0.847±0.19	1.542±0.2	2.143±0.14	1.131±0.22	1.637±0.2
	CF	2.432±0.26	0.896±0.26	1.664±0.3	2.343±0.15	1.189±0.24	1.766±0.2
06.	OF	2.284±0.23	1.112±0.19	1.698±0.1	2.187±0.17	1.535±0.12	1.861±0.2
	CF	2.489±0.19	1.967±0.23	2.228±0.2	2.411±0.12	2.995±0.19	2.703±0.2
07.	OF	2.314±0.18	2.347±0.29	2.331±0.3	2.231±0.23	0	1.116±0.2
	CF	2.491±0.15	2.987±0.21	2.739±0.2	2.467±0.11	2.397±0.18	2.432±0.2
08.	OF	2.171±0.25	2.741±0.23	2.456±0.2	0	0	0
	CF	2.742±0.25	2.941±0.31	2.842±0.3	0	1.527±0.21	0.764±0.2
09.	OF	2.314±0.19	1.821±0.18	2.068±0.2	1.741±0.16	1.471±0.22	1.606±0.2
	CF	2.368±0.32	1.847±0.18	2.108±0.3	2.812±0.13	1.527±0.21	2.812±0.3
10.	OF	1.541±0.23	0.823±0.19	1.182±0.2	1.321±0.18	0.791±0.19	1.056±0.1
	CF	1.623±0.21	0.841±0.19	1.232±0.3	1.378±0.09	0.811±0.13	1.095±0.2
11.	OF	0.839±0.31	0.781±0.19	0.810±0.3	0.849±0.22	0.694±0.19	0.772±0.3
	CF	0.867±0.19	0.796±0.21	0.832±0.2	0.851±0.11	0.729±0.21	0.790±0.3
Mean	**OF**	**1.646**	**1.191**	**1.419**	**1.265**	**0.675**	**0.970**
	CF	**1.804**	**1.405**	**1.604**	**1.487**	**1.126**	**1.463**

and increasing LAI (Tables 3, 4). R_a declined with the deteriorating environmental conditions for plant physiological processes in September and almost stopped at T<5 °C. R_a was lower by 5% in the OF agroecosystems, particularly in W, than in CF due to a higher crop density and mineral fertilization. This minor difference in LAI between agroecosystems of the assessed FS indicated an appropriate and rather similar nutrient supply for plants in both FS, namely in CF using inorganic fertilizing and in OF using manure. The same tendency, based on long-term studies, has been reported by other researchers (Li et al. 2007).

R_a was higher by 50.8% in CF W than that in OF W owing to the larger LAI (r = 0.8). Mean Ra was 13% higher in the CF G than in OF G agroecosystems. Consequently, the CF agroecosystems performed R_a more intensively and thus contributed more to the atmospheric CO_2 concentration. Nevertheless, R_a emissions were recovered by the photosynthetically assimilated

Table 4

Leaf area index of grassland and wheat agroecosystems (mean ± SE, $p < 0.05$)

Month	FS	LAI ($m^2 m^{-2}$)					
		ley			winter wheat		
		2014	2015	mean	2014	2015	mean
03.	OF	0.469±.02	0.385±0.11	0.427±0.08	0.775±0.14	0.517±0.35	0.646±0.27
	CF	0.482 ±0.06	0.392±0.01	0.437 ±0.05	0.969±0.24	0.523±0.31	0.746±0.29
04.	OF	0.813 ±0.02	0.713±0.02	0.763 ±0.02	1.102±0.06	0.854±0.12	0.978±0.09
	CF	0.828 ±0.01	0.742 ±0.01	0.789 ±0.01	1.242±0.26	0.946±0.24	1.094±0.26
05.	OF	0.936 ±0.01	0.916 ±0.01	0.928 ±0.01	1.117±0.35	1.189±0.07	1.153±0.23
	CF	0.992 ±0.01	0.952 ±0.01	0.972 ±0.01	1.298±0.31	1.219±0.09	1.274±0.21
06.	OF	0.187 ±0.02	0.117 ±0.02	0.154 ±0.03	1.154±0.12	1.238±0.34	1.214±0.23
	CF	0.224 ±0.01	0.112 ±0.01	0.169 ±0.01	1.301±0.24	1.246±0.24	1.275±0.24
07.	OF	0.454 ±0.01	0.324 ±0.01	0.389 ±0.01	1.189±0.07	1.249±0.07	1.116±0.07
	CF	0.541 ±0.01	0.372 ±0.01	0.457 ±0.01	1.318±0.19	1.251±0.09	1.285±0.17
08.	OF	0.632 ±0.02	0.682 ±0.02	0.657 ±0.02	1.211±0.34	1.248±0.34	1.230±0.34
	CF	0.612 ±0.01	0.702 ±0.01	0.665 ±0.01	1.321±0.34	0.054±0.28	0.688±0.31
09.	OF	0.727 ±0.01	0.817 ±0.01	0.773 ±0.01	1.227±0.41	0.064±0.41	0.646±0.41
	CF	0.721 ±0.01	0.822 ±0.01	0.781 ±0.01	1.331±0.21	0.087±0.35	0.709±0.26
10.	OF	0.887 ±0.03	0.887 ±0.03	0.887 ±0.03	0.087±0.12	0.102±0.12	0.095±0.12
	CF	0.761 ±0.01	0.892 ±0.01	0.827 ±0.01	0.098±0.23	0.108±0.19	0.103±0.21
11.	OF	0.912 ±0.01	0.908 ±0.03	0.910 ±0.02	0.121±0.11	0.121±0.21	0.121±0.17
	CF	0.842 ±0.01	0.924 ±0.02	0.883 ±0.02	0.151±0.21	0.119±0.18	0.135±0.21
Mean	**OF**	**0.669**	**0.638**	**0.654**	**0.887**	**0.733**	**0.799**
	CF	**0.667**	**0.656**	**0.664**	**1.003**	**0.617**	**0.812**

CO_2 bulk, which was accumulated in the biomass, or GPP (Figure 3). Considering OF-CF variations, GPP was 10.85- 12.71 and 12.52-12.96 μmol $m^{-2}s^{-1}$ for G and W, in spring, 18.31 - 19.15 and 8.69- 11.91 μmol $m^{-2}s^{-1}$ in summer, and 13.68-12.27 and 11.13-10.75 μmol $m^{-2}s^{-1}$ in autumn, respectively.

Strong correlation between GPP and T_a was determined ($r = 0.8$). Consequently, the greatest C amount was associated with the assimilation and sequestration in biomass (GPP) at the highest daily Ta (16.1°C - 18.7°C). In agreement with previous findings (Jans et al., 2010), the GPP data also strongly depended on soil parameters (T_s $r = 0.8$, M $r = -0.7$) and crop management technologies, which are significant for the formation of the C assimilation surface by crops ($r = 0.8$). However, the mean seasonal GPP was determined to be higher by 7% ($p = 0.71$) and 12% ($p = 0.82$) in CF G and W agroecosystems, respectively, than that in the OF and thus revealed a statistically insignificant effect of a farming system on the atmospheric C sink.

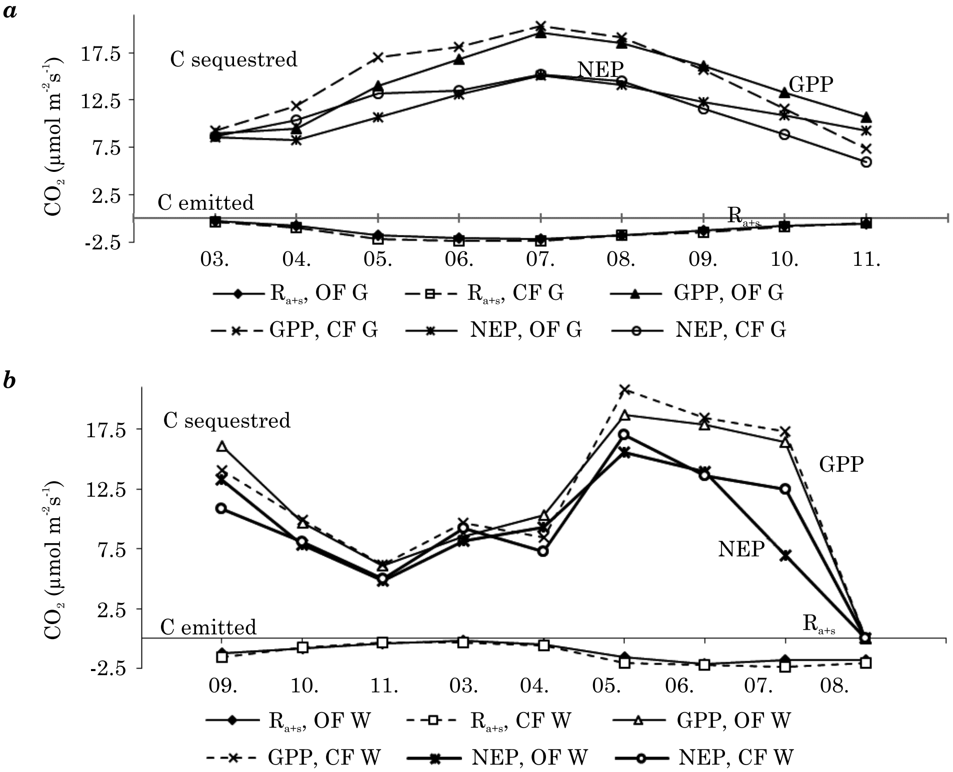

Fig. 3. Mean C exchange in organic and conventional ley (*a*) and winter wheat (*b*) agroecosystems (mean ±SE; $p < 0.05$)

Seasonal C flows might be different in human-controlled ecosystems (Smith et al. 2003); therefore, it is essential to understand and clarify their ability to reduce and to sequester atmospheric C in NEP. The largest NEP was 15.55-16.97 µmol $m^{-2}s^{-1}$ in May and 13.58-13.91 µmol $m^{-2}s^{-1}$ in June in the CF and OF W due to the intense light and other optimal conditions for CO_2 assimilation and C accumulation in biomass. Carbon was gained in the beginning of each spring/summer and then was lost following G cuts and W harvesting in early August each year. The cumulative NEP became very small at the onset of freezing temperatures in late October and continued to decrease until the next spring. NEP was determined to be larger for G (11.48 and 11.58 µmol $m^{-2}s^{-1}$, respectively) than W crops (8.93 and 9.42 µmol $m^{-2}s^{-1}$, respectively) as a result of the longer plant growing period of the ley (Figure 3). Nonetheless, comparing the farming types, NEP was determined to be bigger (only by 1% of G, $p = 0.93$ and by 5% of W, $p = 0.76$) in CF agroecosystems than in OF agroecosystems.

The C content sequestered in the NEP gain correlated with the LAI (r = 0.5 and 0.8 in OF and CF G and r = 0.6 in OF-CF W) and abiotic environmental conditions such as Ta (r = 0.6 and 0.3 in OF and CF G; r = 0.2 and

0.8 in OF and CF W) and T_s (r = 0.4 and 0.8 in OF and CF G; r = 0.1 and 0.2 in OF and CF W). The NEP gain was specifically correlated with T, reaching maximum values during the warmest season and diminishing with decreasing temperatures. A negative correlation (r = -0.2 and -0.4 in OF and CF G; r = -0.4 and -0.3 in OF and CF W) was determined between NEP and M because the surplus soil moisture. This has also been reported by other authors (Zhang et al. 2013).

However, R_a nearly equally the reduced mean NEP, on average by 9% in G and 11% in W crops of both OF and CF agroecosystems. Additionally, R_s reduced the mean NEP by 10 and 11% in G, and by 9 and 12% in W of the OF and CF agroecosystems, respectively. Consequently, due to more intensive R_s emissions into the atmosphere in CF agroecosystems, the mean NEP was lower by 11% in G and 18% in W, than that in OF. Therefore, the choice of a proper crop and right management techniques might be effective for reducing atmospheric CO_2 and thus mitigating climate change. The G of both OF and CF sequestered more atmospheric CO_2 and produced greater NEP than W agroecosystems and thus remained an appropriate means for mitigating the impact of agriculture on climate change, thereby increasing environmental sustainability. Although ley residues accumulate in the soil and improve its fertility, a large amount of assimilated and accumulated C is removed from the field with the harvested biomass. However, OF and CF G applicability is specific; therefore, the potential to increase its areas in agriculture is limited.

Summarising, the sequestered net C gain that accumulated in plant biomass (NEP) generally depended on a crop and environmental conditions rather than on a farming system. Therefore, C exchange assessment might be applied for an evaluation of agricultural impact on the environment, supporting the choice of sustainable agricultural technologies and crops. Moreover, crops are changed every year in a crop rotation system, and thereafter, long-term accumulation of carbon in aerial plant parts is impossible in the field due to its removal in the harvested biomass.

CONCLUSIONS

The data revealed that the variation of respirational CO_2 emissions was dependent on the season, particularly on a month, and on changing environmental conditions in both farming systems.

The revealed different R_a, GPP and NEP values in the C exchange of the assessed agroecosystems were dependent on the leaf area index and seasonal meteorological conditions (specifically, precipitation and temperature in the summer season). The analysis of carbon fluxes exhibited that the ley and winter wheat agroecosystems of organic and conventional farming sequestered and assimilated a similar but larger amount of atmospheric CO_2 than that emitted during respiration. Summarising, a crop and farming system can modify the sequestration of atmospheric CO_2 by means of changes in ecosystem functioning, viz. the capacity of respiration and C assimilation, biometrical parameters, etc.

Nonetheless, the difference between carbon budgets for OF and CF agroecosystems was insignificant, and thus a crop might be a more important factor than a farming system in planned rotation. Specifically, ley is preferred over wheat (irrespective of a farming system) in curbing the atmospheric C in biomass. Targeting environmental sustainability, the C exchange or NEP gain assessment in various agroecosystems can be used as indicators for an evaluation of the agricultural contribution to the atmospheric C pool, supporting the choice of sustainable agricultural technologies and crops to reduce CO_2 emissions and mitigate climate change. Over large-scale crop areas, a complete evaluation of impacts of a farming system choice would support producers in maintaining or increasing ley area.

REFERENCES

Aertsens J., De Nocker L., Gobin A. 2013. *Valuing the carbon sequestration potential for European agriculture*. Land Use Policy, 31:584-594.

Baležentienė L., Kusta A. 2012. *Reducing Greenhouse Gas Emissions in Grassland Ecosystems of the Central Lithuania: Multi-Criteria Evaluation on a Basis of the ARAS Method*. The Sci. World J., 1: 11.

Borken W., Davidson E.A., Savage K., Gaudinski J., Trumbore S.E. 2003. *Drying and wetting effects on carbon dioxide release from organic horizons*. Soil Sci. Soc. Am. J., 67: 1888-1896.

Ciais P., Wattenbach M., Vuichard N., Smith P., Piao S.L., Don A., Luyssaert S. et al., 2010. *The European greenhouse gas balance revisited*. Part 2. *Croplands*. Global Change Biol., 16: 1409-1428.

Chapin F.S., Woodwell G.M., Randerson J.T., Rastetter E.B., Lovett G.M., Baldocchi D.D., Clark D.A. et al. 2006. *Reconciling carbon-cycle concepts, terminology, and methods*. Ecosystems, 9(7): 1041-1050.

Chen S., Zou J., Hu Z., Chen H., Lu Y. 2014. *Global annual soil respiration in relation to climate, soil properties and vegetation characteristics: Summary of available data*. Agric. For. Meteorol., 198-199: 335-346.

FAO. 2013. *Statistical Yearbook. World Food and Agriculture*. Rome.

IPCC. 2007. *International Panel on Climate Change. Summary for policy makers*. Cambridge University Press, Cambridge.

Jans W., Jacobs C., Kruijt B., Elbers J. A., Barendse S., Moors E.J. 2010. *Carbon exchange of a maize (Zea mays* L.*) crop: Influence of phenology*. Agr. Ecosyst. Environ., 139: 316-324.

Kauer K., Tein B., de Cima D.S., Talgre L., Eremeev V., Loit E., Luik A. 2015. *Soil carbon dynamics estimation and dependence on farming system in a temperate climate*. Soil Till Res, 154: 53-63.

Lee X., Wu H.J, Sigler J., Oishi C., Siccama T. 2004. *Rapid and transient response of soil respiration to rain*. Glob Change Biol., 10: 1017-1026.

Li J., Zhao B., Li X. 2008. *Effects of long-term combined application of organic and mineral fertilizers on microbial biomass, soil enzyme activities and soil fertility*. Agric. Sci. China, 7: 336-343.

Macek I., Pfanz H., Francetic V., Batic F., Vodnik D. 2005. *Root respiration response to high CO_2 concentrations in plants from natural CO_2 springs.* Environ. Exp. Bot., 54: 90-99.

Raich JW, Tufekcioglu A. 2000. *Vegetation and soil respiration: correlations and controls.* Biogeochemistry, 48: 71-90.

Samouelian A., Cousin I., Richard G., Tabbagh A., Bruand A. 2003. *Electrical resistivity imaging for detecting soil cracking at the centimetric scale.* Soil Sci. Soc. J. Am., 67: 1319-1326.

Smith P., Lanigan G., Kutschc W.L., Buchmannd N., Eugsterd W., Aubinete M. et al. 2010. *Measurements necessary for assessing the net ecosystem carbon budget of croplands.* Agr. Ecosyst. Environ., 139: 302-315.

Suyker A.E., Verma S.B., Burba G.G.2003. *Interannual variability in net CO_2 exchange of a native tallgrass prairie*. Global Change. Biol., 9(2): 255-265.

Taylor A.M., Amiro B.D., Fraser T.J. 2013. *Net CO_2 exchange and carbon budgets of a three-year crop rotation following conversion of perennial lands to annual cropping in Manitoba, Canada.* Agr. Forest Meteorol., 182: 67-75.

Wu C., Han X., Ni J., Niu Z., Huang W. 2010. *Estimation of gross primary production in wheat from in situ measurements*. Int. J. Appl. Earth Obs. Geoinf., 12: 183-189.

Zhang X.B., Xu M.G., Sun N., Wang X.J., Wu L., Wang B.R., LI D.C. 2013. *How do environmental factors and different fertilizer strategies affect soil CO_2 emission and carbon sequestration in the upland soils of southern China.* Appl. Soil Ecol., 72: 109-118.

Zhang Y., Gan Z., Li R., Wang R., Li N., Zhao M., Du L., Guo S., Jiang J., Wang Z. 2016. *Litter production rates and soil moisture influences interannual variability in litter respiration in the semi-arid Loess Plateau, China*. J. Arid Environ., 125: 43-51.