Soil respiration response to abiotic parameters in ley and winter wheat agroecosystems

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Soil CO_2 emissions comprise the biggest (60-90%) part of the global C-cycle, increasing the anthropogenic CO_2 emissions into the atmosphere. Therefore the choice of agro-technologies and crops mitigating the climate change is becoming an important challenge for the agro sector. The comparison of both farming type, i.e. organic (OF) and conventional (CF), and environmental impact on carbon exchange in ley (G) and winter wheat (W) agroecosystems were carried out in 2014 – 2015 in the Training farm of the Aleksandras Stulginskis University.

Comparing with the CF, the OF reduced the mean soil respiration by 12% ($p = 0.31$) and 13% ($p = 0.55$), in ley and wheat agroecosystems respectively. The determined strong positive correlation between soil respiration and temperature ($r = 0.8$, $p = 0.25$), moisture content ($r = -0.7$, $p = 0.04$), electrical conductivity ($r = 0.3$, $p = 0.47$) confirmed the impact of soil physical properties on CO_2 emissions from soil to atmosphere.

Keywords: soil respiration, crops, temperature, moisture, el. conductivity.

Introduction

Croplands represent about 12% of the Earth's surface and one third of the land surface in Europe, and thus their importance for the climate change is evident. Plants and soils in agroecosystem are actively involved in the formation of climate, significantly assimilating and accumulating in biomass high carbon pool. Currently, agriculture produced 12-15% (9% in the EU), or 5.1-6.1 Gt CO_2 –eq. yr^{-1} of all anthropogenic GHG emissions (IPCC, 2007; FAO …, 2013).

Meteorological parameters, especially temperature, have strongly influenced the soil CO_2 emissions (Baležentienė, Kusta, 2012; Rastagi et al., 2003). Precipitation, even scanty, activates the soil biota and CO_2 emissions from the soil (Lee et al., 2004).

Agroecosystems are the prevailing ecosystem type, which represent 53.1% of the territory in Lithuania and generate 4.945 10^{-3} Gt or 23.4% CO_2 emissions of all Lithuanian economic entities (Environment…., 2010). However, the performed studies have focused only on soil carbon dynamics or CO_2 emissions (Baležentienė, Kusta, 2012), then precise and detailed data on carbon emissions in agroecosystems of organic and conventional at the regional level are lacking. Therefore the assessment how of agro technological, soil and meteorological conditions impacted on C budget could be substantial for the shifting of C exchange into the direction of CO_2 emissions reduction, predicting the changes in agroecosystems and supporting environmental sustainability when choosing a land-use types and management practices. For the better understanding of the environmental and farming management factors affecting inter-annual variability in CO_2 emissions it is critical to precisely understand local carbon cycling, especially in the changing climate.

The main objective of this study was to evaluate the impact of organic and conventional farming on soil CO_2 emissions in leys and winter wheat agroecosystems. Extra objective of the study was to quantify the impact of meteorological (temperature and precipitation) and soil conditions (temperature, humidity, and electric conductivity) on soil respiration emissions in ley and winter wheat agroecosystems.

Material and Methods

Experimental site. The investigation of environmental impact on carbon accumulation in biomass and its budget in leys (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 from 2014 to 2015 in 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 active in the Training Farm. OF has been certified by the EKOAGROS (Lithuanian Committee for Organic Agriculture).

The cropland soil types were *Luvisols: Hapli-Epihypogleyic Luvisol*, *LVg-p-w-ha* in the OF and CF ley fields or *Albi-Epihypogleyic Luvisol*, *LVg-p-w-ab* in the OF and CF wheat fields (FAO/UNESCO, 1997).

Measurements and analysis of siol respiration and abiotic parameters were performed every 7-10 days dependent on the meteorological conditions. The measurement sites, were set out randomly every 50 - 100 m in linear transects, oriented by N- S direction in the fields (Fig. 1). The measurement sites were set out at a minimum distance of 20 - 25 m from the field edge to avoid margin effect. The measurement plots (b) in 6 replications were installed in each site.

For the estimation of the soil respiration (R_s), the CO_2 emissions in daytime, was measured using the closed chamber method (Smith et al, 2003) with a portative measurement system (LCpro, ADC Bioscientific LTD, UK).

Assessments of CO_2 emissions were carried out in differently managed organic (OF) and conventional (CF) agroecosystems of ley (G) and winter wheat (W). Perennial grass mixture composed of 50% of red clover (*Trifolium pretense*) '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}) cover crops in 2013 05 07. 2-cut system was applied in leys on 2014 (06 04 and 08 11) and 2015 (06 02 and 08 06).

Soil parameters. To evaluate the physical parameters impact on the CO_2 emission the following soil parameters, specifically temperature (T_s, °C), humidity (M, %), electrical conductivity (EC, mS cm^{-1}) were determined in 10 cm depth by the integrated sensor (HH2 AT Delta-T DevicesLtd, WET-2).

The joint soil samples were taken using cylindrical auger in each field. Soil agrochemical analysis (ISO10381-2: 2002) was carried out in Agrochemical Research Laboratory of Lithuanian Agriculture and Forestry Research Centre.

Meteorological conditions. The vegetation period suitability for plant growth is expressed as a ratio of humidity and temperature, or hydrothermal coefficient (HTK) (Fig. 1).

2014 March HTK = 1.83 shows the extent moisture, and in April HTK = 0.78 - too dry conditions for plant growth, or 2 times drier than in March. May HTK = 2.03 June HTK = 1.13, July HTK = 0.82, August HTK = 2.02, September HTK = 1.98. October HTK = 1.61, or nearly optimal humidity, while November HTK = 4.15 indicates 3 times more moisture than in October.

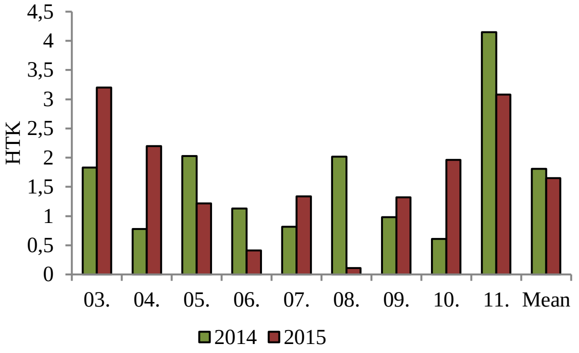

Fig.1. Hydrothermal coefficients (HTK) of the 2014-2015 seasons
1 pav. *hidroterminiai koeficientai 2014-2015 m. sezonų*

2015 spring was too wet for plant growth, since March HTK = 3.2, April HTK = 2.2, May HTK = 1.22, but June was too dry with HTK = 0.41, July HTK = 1.34, and in August, there was no rain all with HTK = 0.11, September HTK = 1.32, October HTK = 1.96.

Summarizing, 2015 growing season was warmer but drier in comparison with 2014 and maT/maP. This is confirmed by the average hydrothermal coefficient (HTK), which was 1.81 in 2014 and 1.47 in 2015. Fluctuations and differences in weather conditions could affect not only autotrophs biometric parameters, but also photosynthesis and respiration processes.

Statistical data analysis. For 2014-2015 environmental conditions and soil parameters: temperature (T_s, °C), moisture (M, %) and electrical conductivity (EC, mS cm^{-1}) were counted mean values and standard error (mean±SE). For the quantitative evaluation of data, comparing organic and conventional agroecosystems was used Student's t test, letting to evaluate if there was a statistically significant difference between data. The difference was considered significant if $P<0.05$. Correlation between CO_2 emissions and environmental conditions was evaluated with the correlation coefficient r. Data was considered statistically reliable at probability level of $p <0.05$ and evaluated with STATISTICA software package.

Results and discussion

Soil seasonal CO_2 emissions (Rs) significantly depended on the season meteorological conditions and soil parameters which impacted various lifecycle processes of crops and soil biota (Fig. 2). Though T_s ranged between 4.6 and 25.8°C ($p = 0.59$) during the plant vegetation season, these differences did not depend on the farming type and the crop species and (Fig. 2a). However, slightly higher Ts in CF crops induced more intensive processes of soil biota and resulted in an average of 12% higher R_s emissions than in OF agroecosystems. Strong correlation r = 0.7 and 0.8 (p=0.47-0.50) between the mean Rs and Ts was found a in all tested crops and farming types. Ts conditioned soil ability to supply plants by nutrient materials along with forming multi-complex relationships between different agroecosystem components, which are also conditioned by internal and external factors (Smith et al., 2003).

Similar to T_s, the soil moisture M depended on the amount and frequency of precipitation, and strongly negatively correlated with R_s (r=-0.6 and r = -0.7). This is consistent with conclusions of previous researchers (Smith et al., 2003) that there is a strong correlation between Rs and the M and Ts. However, the response of R_s to M is complex, as R_s is restricted in case of low and high soil moisture content, and the response rate may also be confounded by soil temperature (Zhang et al., 2016). Though due to the climate change the loss of soil moisture is stated in the world (Schlesinger and Bernhardt, 2013), there is soil moisture surplus during autumn and spring, which is leading to anaerobic conditions, unfavourable for the soil biota and plant roots in our temperate climate case. Therefore, R_s decreased with decreasing T_s and M, generally in autumn in the assessed agroecosystems. Furthermore, there was specified stronger positive M effect on R_s alterations (r = 0.8, p <0.05) in the summer period (06.-09.), than during the cooler autumn and spring periods (r = 0.2) (Fig. 2b).

Numerous researchers (Borken et al., 2003; Lee et al., 2004, Chen et al., 2014) explained such correlation between positive T_s and M not only by their direct effects on soil physical properties, but also by increased biological activity of the soil. Moreover, Raich and Tufekcioglu (2000) maintained that soil respiration increased with a 10°C increase in temperature.

Soil EC mostly depended on soil physical and chemical properties, namely texture, salinity or water content (Samouėlian et al., 2005). This indicator depended on dissolved ions in the soil, which is targeting both the behaviour of soil biota (Macek et al., 2005) and Rs emissions. In our case, Rs also altered along crops being subjected on 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).

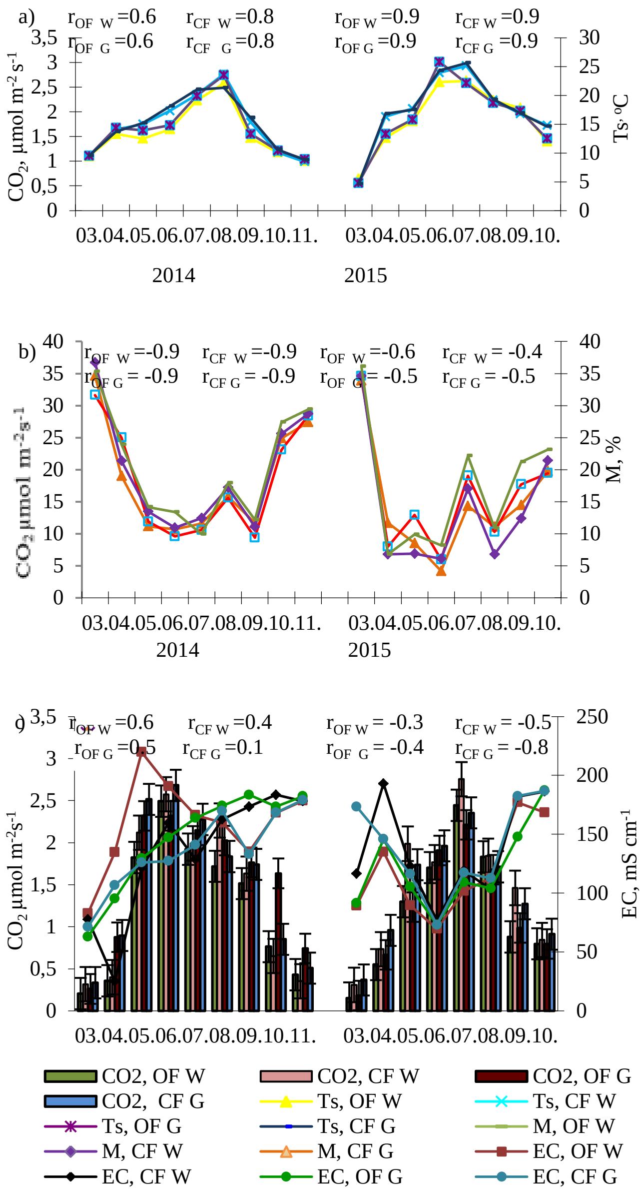

Fig. 2. Correlation between soil respiration and temperature (a), moisture content (b), and the electrical conductivity (c) in grassland and wheat agroecosystems of organic and conventional farming during 2014-2015 (mean±SE; $p<0.05$). Rs - soil respiration, T_s – soil temperature, M – soil moisture, EC - electrical conductivity, G - ley, W – wheat, OF - organic farming, CF - conventional farming.

***2 pav.** Koreliacija tarp dirvožemio respiracijos ir temperatūros (a), drėgmės (b) ir elektrinio laidumo (c) ekologinės ir intensyvios žemdirbystės daugiamečių žolių ir kviečių agroekosistemose 2014-2015 (vid.±SE; p<0,05). Rs - dirvožemio respiracija, T_s – dirvožemio temperatūra, M – dirvožemio drėgnumas, EC - elektrinis laidumas, G - daugiametės žolės, W – kviečiai, OF – ekologinė žemdirbystė, CF - intensyvi žemdirbystė.*

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 variance of M and ion concentration of mineral fertilizers in soil solution. The highest mean EC and its strong positive correlation with a R_s was determined in moister 2014 in OF W (159.5 mS cm^{-1}, r = 0.6) and OF G (145.8 mS cm^{-1}, r = 0.5) due to higher M. 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 warmer and drier 2015.

The measured EC parameters related with meteorological conditions, but the mean rates were similar in agroecosystems representing sufficient ion amount in the soil solution, and thus favourable conditions for the plant and soil biota vegetation.

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 researchers (Kauer et al. 2015), higher R_s was estimated in OF crops, and thus indicated more favourable environmental conditions for soil biota life and physiological processes in plant root than within CF, which are formed and maintained due to the different crop management techniques. Though R_s emissions differed between the assessed agroecosystems, however it can be controlled by optimizing or selecting sustainable agro-technologies and crop species.

Conclusions

This research revealed that both organic and conventional agriculture has the potential to emit carbon dioxide (CO_2), making croplands important in terrestrial carbon (C) cycles, where they dominate the anthropogenized landscape. C budget in organic and conventional farming of grasslands and winter wheat varies with environmental factors. It was found that respirational CO_2 emissions changed depending on the vegetation period, particular month, and changing environmental conditions in both farming types. Regardless of the autotroph species was found a strong positive correlation between respiration CO_2 emissions and soil temperature (r = 0.8, p = 0.25), strong negative - with soil moisture content (r = -0.7, p = 0.04) and average - with soil electrical conductivity (r = 0.3, p =0.47).

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Dirvožemio respiracijos atsakas į abijotinius parametrus daugiamečių žolių ir žieminių kviečių agoekosistemose

Santrauka

Dirvožemio CO_2 emisijos sudaro didžiausią globalaus C-ciklo dalį (60-90%), didindamos antropogenines CO_2 emisijas į atmosferą. Todėl agrotechnologijų ir augalų, švelninančių klimato kaitą pasirinkimas tampa svarbiu iššūkiu agrosektoriui. Palyginimas abiejų žemdirbystės sistemų, t.y., ekologinės (OF) ir intensyvios (CF) bei aplinkos poveikio anglies apykaitai trumpaamžių sėjomainos daugiamečių žolių ir kviečių agroekosistemose buvo vykdytas Aleksandro Stulginskio Mokomajame ūkyje2014-2015 m.

Lyginant su CF, OF vidutinę dirvožemio respiraciją sumažino 12% ($p = 0{,}31$) ir 13% ($p = 0{,}55$) atitinkamai žolių ir kviečių agroekosistemose. Nustatyta stipri teigiama koreliacija tarp dirvožemio ir temperatūros ($r = 0{,}8$, $p = 0{,}25$), drėgmės kiekio ($r = -0{,}7$, $p = 0{,}04$), elektrinio laidumo ($r = 0{,}3$, $p = 0{,}47$) patvirtino dirvožemio fizinių parametrų poveikį CO_2 emisijoms iš dirvožemio į atmosferą.

Soil respiration, crops, temperature, moisture, el. conductivity.

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