The effect of soil macroporosity, temperature and water content on CO₂ efflux in the soils of different genesis and land management

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Abstract
This paper analyses the effects of soil macropores, temperature and water content on soil carbon dioxide (CO₂) efflux behaviour, which could help understand the mechanism of CO₂ efflux as influenced by soil type and land use methods. The temporal dynamic changes of CO₂ efflux from the soil surface using a closed chamber method (LI-COR LI-8100A Automated Soil CO₂ Flux System) were measured. Soil CO₂ efflux was investigated at a topsoil depth of 0–5 cm in (1) arable land under conventional tillage on Cambisol (CM), (2) grassland on Cambisol, (3) park on Cambisol, (4) arable land under conventional tillage on Retisol (RT), (5) grassland on Retisol and (6) forest on Retisol. CO₂ emission was measured six times per growing season from May to September in 2017. Soil macropore network was researched by implementing an X-ray computed tomography and carried out at the laboratory of the Institute of Agrophysics, Polish Academy of Sciences in Lublin, Poland. Macropores resulting from soil pedogenesis and land use methods played an important role on soil water, temperature and gas transport. The type of soil vegetation cover and amount of soil macropores significantly influenced soil respiration rate. The efflux values were recorded ranging from 0.71 to 3.43 μmol CO₂ m⁻² s⁻¹ (Cambisol) and from 0.70 to 3.05 μmol CO₂ m⁻² s⁻¹ (Retisol) in the grassland, from 0.43 to 2.57 μmol CO₂ m⁻² s⁻¹ (Cambisol) in the park, from 0.44 to 2.52 μmol CO₂ m⁻² s⁻¹ (Retisol) in the forest, from 0.52 to 2.68 μmol CO₂ m⁻² s⁻¹ (Retisol) and from 0.09 to 1.57 μmol CO₂ m⁻² s⁻¹ (Cambisol) in the conventional tillage. Computational tomography data revealed that the content of macropores amounted to 10.75% in the grassland site, 1.97% in the park and 1.21% in the conventional tillage within the soil depth of 3–8 cm of the Cambisol and 6.45% in the forest, 4.94% in the conventional tillage and 3.86% in the grassland at the same soil depth of the Retisol. Soil temperature, water content and macroporosity were the main factors exerting the influence on soil gas origination rate. The relationship between soil CO₂ efflux and volumetric water content at a 5 cm depth can be described by a linear regression model y = 0.0943x – 0.7651, R² = 0.53 (valid for volumetric water content from 22.5 to 27.0 vol.% on Retisol and from 16.8 to 24.4 vol.% on Cambisol). Also, linear regression model y = 0.1167x – 0.8214, R² = 0.65 showed the relationship between soil CO₂ efflux and soil macroporosity at the 3–8 cm depth. Soil CO₂ efflux displayed a typical polynomial relationship with soil temperature at the 5 cm depth; however, the relationship was very weak. Both soil type and land use methods had a noticeable influence on macroporosity, surface area and macropore range of soil pore-size distribution. The amount of macropores in macropore geometry was an important factor when dealing with CO₂ flow. Topsoil CO₂ efflux under contrasting vegetation cover and management conditions on Cambisol and Retisol was directly related to soil macroporosity and volumetric water content.

Key words: Cambisol, Retisol, volumetric water content, X-ray computed tomography.

Introduction
Soil carbon dioxide (CO₂) efflux is a physical process driven primarily by the CO₂ concentration diffusion gradient between the upper soil layers and the atmosphere near the soil surface. Soil CO₂ production is heavily influenced by environmental factors, including soil temperature, soil moisture, macropores.

The importance of macropores as preferential pathways of water, air and chemicals in the soil has been

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widely recognized (Lin et al., 2005; Jarvis, 2007; Hu et al., 2016). Reconstruction, visualization and quantification of 3-D macropore networks are essential for correlation macropore characteristics to their physical functions and for prediction of their dynamics under diverse land uses. Different types of macropores have distinct geometries and therefore function differently (Luo et al., 2008). Soil type and land use method are among the main factors influencing macropore characteristics (Gantzer, Anderson, 2002; Mooney, Morris, 2008; Udawatta et al., 2008; Zhou et al., 2008; Luo et al., 2010). X-ray computed tomography has been used in recent years as a new method to quantify soil pores, especially macropore development, at a much higher resolution than the previous methods, such as dye tracing, spectral image analysis and thin section (Taina et al., 2008; Munkholm et al., 2012). Soil pore characteristics are important for a large range of essential soil functions such as colloid, water and gas transport, habitat for soil organisms as well as soil mechanical properties such as soil friability (Munkholm et al., 2012).

Greenhouse gas (GHG) emissions from agricultural soils are a substantial contributor to climate change (Smith et al., 2008), there for development of agricultural practices that mitigate GHG emissions from agricultural soils is very important (Mangalassery et al., 2013). Tillage regime has been regarded as one of the important factors affecting efflux from the soils (Li et al., 2013). Tillage management can affect factors controlling soil respiration, soil temperature, soil water content (Li et al., 2006) and macroporosity. Soil moisture and temperature are among the most important factors controlling soil CO₂ emissions (Lopes de Gerenyu et al., 2005; Schaufler et al., 2010; Ni et al., 2012). Under dry conditions, the soil CO₂ efflux is lower because root and micro-organism activity is typically low. Increasing the soil water content normally increases the bio-activity in the soil. Higher soil water content usually causes soil respiration increase. But if soil water content is very high, the total soil CO₂ efflux is reduced, because of limited diffusion of oxygen and subsequent suppression of CO₂ emission. Soil temperature is the best predictor of the dynamics of the soil CO₂ flux rate. The high positive correlation between CO₂ efflux and soil temperatures was found in natural and agricultural ecosystems of the Russian taiga zone (Kudveyarov, Kurganova, 1998). Schaufler et al. (2010) revealed a non-linear increase of CO₂ efflux with temperature increasing. Tillage regime has been regarded as one of the important factors affecting CO₂ emissions from soils (Li et al., 2013). Soil temperature and soil moisture influence both the production of CO₂ by affecting microorganism and root activity, and the diffusion of gases through the soil pores (Wei et al., 2014).

The goal of this paper is to present the findings on soil carbon dioxide (CO₂) efflux originated from soils of different genesis and under contrasting land use methods. The attention was focused on the evaluation of soil temperature, volumetric water content and the network of the macroporosity effects on soil CO₂ efflux regime.

Materials and methods

Soils and sampling. Two soil types were studied: Endocalcari Endogleyic Cambisol (CM-gln.can-lo. dr) (loam, drain) situated at Institute of Agriculture (55°23’38” N, 23°51’35” E), Lithuanian Research Centre for Agriculture and Forestry in Dotnuva, and Bathygleeyic Dystric Retisol (RT-dy.gld-lo) (loamic) near Bijotai (55°31’12” N, 22°36’55” E), Šilalė distr. The soils are classified according to WRB (2014). Both soil types are representative and commonly found in the Central (Cambisol) and in the Western (Retisol) parts of Lithuania.

The attention was focused on the evaluation of soil carbon dioxide (CO₂) efflux in the soils of different genesis and land management.

Three land use methods on Cambisol:
1) conventional tillage – stubble cultivation (10–12 cm) after crop harvesting; in 2–3 weeks deep (23–25 cm) ploughing; before sowing, shallow cultivation (4–5 cm) 1–2 times; plant residues (straw) chopped and spread in the field; straw mineralization activated by adding nitrogen fertiliser; the crop was beans; 2) grassland – area where the vegetation is dominated by grasses: Medicago sativa, Galega orientalis, Taraxacum officinale, Lolium temulentum and Trifolium repens; 3) park area – the dominant vegetation is trees: Acer platanoides, Tilia cordata, Fraxinus excelsior, and grasses: Aegopodium podagraria, Pulmonaria obscura, Anemone nemorosa.

Three land use methods on Retisol:
1) conventional tillage – stubble cultivation (10–12 cm) after crop harvesting; in 2–3 weeks deep (23–25 cm) ploughing; before sowing, shallow cultivation (4–5 cm) 1–2 times; plant residues (straw) chopped and spread in the field; straw mineralization activated by adding nitrogen fertiliser; the crop was winter wheat; 2) grassland – area where the vegetation is dominated by grasses: Leontodon autumnalis, Festuca ovina, Dactylis glomerata, Taraxacum officinale and Trifolium repens; 3) forest – the dominant vegetation is trees Quercus robur and Acer platanoides, and grasses Aegopodium podagraria, Pulmonaria obscura and Anemone nemorosa. Thus, there were six treatments investigated in this study: Cambisol-grassland, Cambisol-conventional tillage, Cambisol-park, Retisol-grassland, Retisol-conventional tillage and Retisol-forest.

For soil macropore network determination, one intact soil column for scanning with a computed tomography, 50 mm in diameter and 50 mm in length was sampled from each treatment at the 3–8 cm soil depth on April 20, 2017 on Cambisol and on May 12, 2017 on Retisol. Samples were taken to carefully push polyvinyl chloride pipe vertically and gradually into the soil. The soil inside the cylinders was secured with two plastic caps for natural soil water content preservation. Undisturbed soil cores were stored in a refrigerator at a constant 3–4°C temperature.

Carbon dioxide (CO₂) efflux measurements and characterization. In this research we investigated the temporal dynamic changes of CO₂ efflux (µmol m⁻² s⁻¹) from the soil surface using a closed chamber method – LI-COR LI-8100A Automated Soil CO₂ Flux System (LI-COR Inc., USA). Soil CO₂ efflux was determined from the topsoil in: 1) arable land under conventional tillage on Cambisol, 2) grassland on Cambisol, 3) park on Cambisol, 4) arable land under conventional tillage on Retisol, 5) grassland on Retisol and 6) forest on Retisol. Each CO₂ efflux measurement was done in three replications. Measurement of CO₂ efflux was carried out six times per growing season from May to September, 2017, at the same time of the day (from 10 a.m. to 5 p.m.) and at the fixed locations in the site. Soil temperature (T-soil) and volumetric water content (VWC) were measured at the 5 cm depth using a portable HH2 WET sensor. It was determined at the same time and same site with CO₂ efflux measurements.

X-ray computed tomography. X-ray computational tomography (XRT) analysis of soil samples (50 mm in
Institute of Agrophysics, Polish Academy of Sciences, laboratory of X-ray Computed Tomography (Lamorski, 2017) in October 2017 using a device GE Nanotom 180S (GE Sensing & Inspection Technologies GmbH, Germany). Each XRT measurement was done in a single copy. The scan resolution, i.e. voxel size was 0.0215 mm. The parameters of the XRT acquisition were as follows: X-ray source voltage 150 kV, X-ray source current 40 µA and 0.2 mm Cu filter was used to avoid beam hardening effect. During the XRT scan, the samples were rotated in 360° and 1200 2D radiograms were recorded. The recorded radiograms were averages of 12 2D images taken at the same angular position to minimize the detector noise. The next step was three-dimensional (3D) soil sample image reconstruction based on the recorded two-dimensional (2D) radiograms. Reconstruction was done using software DatosX 2.0 (GE Sensing & Inspection Technologies GmbH). As a result, 16 bit grey-level 3D images were generated. Image analysis was performed using VG Studio Max 2.0 (Volume Graphics GmbH, Germany), Fiji (National Institutes of Health, USA) and software Avizo 9 (Field Electron and Ion Company, USA). The first step was the region of interest selection and extraction of the soil core image from the whole 3D scanned volume. Next step included the median filtering with kernel size 3px to minimize the noise before thresholding the images. Thresholding was done using IsoData algorithm (Ridler, Calvard, 1978) with thorough inspection of the thresholded images. After that the labelling of the detected pores was performed. The group of voxels connected by at least one voxel face was treated as an individual pore. As a result of the labelling, the volumes, surface and equivalent diameter of individual macropores were determined.

**Description of meteorological conditions.**

Climatic peculiarities are determined by both continental and oceanic factors. The mean annual air temperature in Lithuania is close to 6°C, and mean annual amount of precipitation varies from 620 to 700 mm and more. Precipitation in 2017 amounted to 736.1 mm in the central part and to 1276.1 mm in the western part of Lithuania. In 2017, there were 117 days with precipitation in Dotnuva and 200 days in Bijotai.

**Statistical analysis.** The statistical software package SAS 7.1 (SAS Inc., USA) was used for all data analysis. The data was compared using Fisher’s least significant difference (LSD) test at the probability levels $P < 0.05$ and $P < 0.01$. Simple linear regressions were carried out to examine the relationship between different parameters. Correlation-regression analysis was also implemented.

**Results and discussion**

The effect of land use methods on soil CO$_2$ efflux, temperature and water content. All processes taking part in the soil are closely interrelated. Changes in weather patterns caused by the climate change, including droughts and extreme events, have a significant influence on greenhouse gas emission (Putramentaite et al., 2014).

According to literature, the soil CO$_2$ efflux peaked at intermediate soil moisture and decreased under dry conditions and under water-saturation conditions (van Straaten et al., 2009). This trend was observed in our investigations under different land use methods of Retisol and under conventional tillage and park of Cambisol. In grassland of Cambisol this relationship was not registered because soil temperature affected the efflux of CO$_2$ (Figs 1–3). Temporal variations of soil CO$_2$ effuxes are summarized in Figure 1. Generally, the effuxes increased gradually after sowing, reached the maximum between the end of July to mid-August on Cambisol, between the beginning of June to mid-July on Retisol, and then declined gradually until mid-September (Fig. 1).

Soil temperature varied from 9.8°C to 26.3°C during the experiment period, with averages of 17.4°C and 16.9°C at 5 cm depth on Cambisol and Retisol, respectively (Fig. 2).

Soil volumetric water content at 5 cm depth averaged 20.4% and 25.2% on Cambisol and Retisol, respectively (Fig. 3). Volumetric water content on Retisol was profoundly higher than that on Cambisol during the whole experimental period.

![Figure 1](image1.png) **Figure 1.** The changes in soil carbon dioxide (CO$_2$) efflux under different soil types and land use methods during vegetation period

![Figure 2](image2.png) **Figure 2.** The changes in soil temperature (T-soil) under different soil types and land use methods during vegetation period
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The influence of land use methods was significant \((P < 0.01)\) for CO$_2$ efflux, soil temperature and volumetric water content (Table 1).

**Correlation between CO$_2$ efflux, soil temperature (T-soil) and volumetric water content (VWC).** The correlation matrix between the investigated indices and CO$_2$ efflux is presented in Table 2. Significant correlation between CO$_2$ efflux and soil temperature through the whole period of observations was recorded under all land use methods of Cambisol. Such relationship was not established in the soil management systems of Retisol. Significant correlations between soil CO$_2$ efflux and volumetric water content were observed in grassland treatment in Cambisol and Retisol, and in forest in Retisol only. Significant correlations \((P < 0.01)\) in treatments of Retisol were observed between volumetric water content and soil temperature and \((P < 0.05)\) in grassland of Cambisol.

**The relationships between soil CO$_2$ efflux and soil temperature and volumetric water content (VWC).**

During the whole growing season, correlation analyses showed poor interrelation between soil CO$_2$ efflux and soil temperature at 5 cm depth \((P > 0.05)\). The relationship between CO$_2$ efflux and volumetric water content was positive \((R^2 = 0.53, P < 0.05)\) (Fig. 4). This indicated that the volumetric water content was one of the main factors limiting the rate of CO$_2$ efflux from the different landuse treatments.
soils of different land use methods for this period. This finding is in line with the data found in literature (Lopes de Gerenyu et al., 2005; Wei et al., 2014).

**Visualization of macropore networks.** A three-dimensional (3D) visualization of macropores in the six soil columns are shown in Figures 5 and 6.

The macropores formed by roots were highly continuous and round in shape. The smaller and more randomly and less continuously distributed macropores were likely inter-aggregate macropores, such as those formed by freezing and thawing or wetting and drying (Luo et al., 2010). The macropores for the conventional tillage (C-CT) and the park (C-P) were less abundant as compared to those in the grassland (C-G), while were less tortuous and somewhat smoother (Fig. 5). Many continuous and tubular pores, formed by decayed plant roots of perennial grasses, were also observed in both the grassland: C-G (Fig. 5) and R-G (Fig. 6).

**Figure 4.** The relationship between soil carbon dioxide (CO₂) efflux and volumetric water content (VWC) at the 5 cm depth under different soil types and land use methods.

**Figure 5.** Three-dimensional (3D) visualization of soil macropore networks for the soil columns (44.81 mm in diameter and about 38.2 mm in vertical length after cutting) in Cambisol (C) of conventional tillage (C-CT), grassland (C-G) and park (C-P) at the 3–8 cm depth.

**Figure 6.** Three-dimensional (3D) visualization of soil macropore networks for the soil columns (44.81 mm in diameter and about 38.2 mm in vertical length after cutting) in Retisol (R) of conventional tillage (R-CT), grassland (R-G) and forest (R-F) at the 3–8 cm depth.

Macropore characteristics differed among the different soil type and land use methods treatments. The volume of different size of macropores is provided in Figure 7.

**Macroporosity, surface area and macropore range of soil pore-size distribution.** The macropore characteristics of all soil type and land use methods are listed in Table 3. The macroporosity for the grassland of Cambisol was the highest – 0.065 m³ m⁻³. It was six times higher compared to the two other land use methods, i.e. 0.007 m³ m⁻³ for the conventional tillage of Cambisol, and 0.012 m³ m⁻³ for the park of Cambisol and over twice higher compared to grassland (0.023 m³ m⁻³, R-G) conventional tillage (0.029 m³ m⁻³, R-CT) and forest (0.039 m³ m⁻³, R-F). The total surface area and macropore network density varied among the different soil type and land use methods in a way similar to that of macroporosity.

The grassland of Cambisol had the greatest total surface area for the entire column (69521.1 mm²) and macroporosity (0.065 m³ m⁻³), while the conventional tillage of Cambisol had the lowest – 8150.5 mm² for total surface area and 0.007 m³ m⁻³ for macroporosity.

**Correlation between different macropore characteristics.** Brewer (1964) has classified macropores according to the size into coarse (>5000 µm), medium
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**Figure 7.** The volume of different size of macropores under different land use methods and soil types

**Table 3.** Macropore characteristics under different soil types and land use methods

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Land use method</th>
<th>Macroporosity m$^{-3}$</th>
<th>Total surface area mm$^2$</th>
<th>Mean pore size mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambisol</td>
<td>conventional tillage</td>
<td>0.007</td>
<td>8150.5</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>grassland</td>
<td>0.065</td>
<td>69321.1</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>park</td>
<td>0.012</td>
<td>18135.5</td>
<td>0.26</td>
</tr>
<tr>
<td>Retisol</td>
<td>conventional tillage</td>
<td>0.029</td>
<td>25934.2</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>grassland</td>
<td>0.023</td>
<td>32484.9</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>forest</td>
<td>0.039</td>
<td>37830.5</td>
<td>0.26</td>
</tr>
</tbody>
</table>

(2000–5000 µm), fine (1000–2000 µm) and very fine (75–1000 µm). Macropore range of soil pore-size distribution under different land use methods and soil types is presented in Figure 7.

The correlation matrix between the different soil types and macropores sizes investigated is presented in Table 4. Significant correlations ($P < 0.01$) were observed between medium and fine and between fine and very fine pores ($P < 0.05$) for all the soil samples under different land use methods and soil types.

The correlation analysis revealed that the volume of macropores, surface area and macropore size were highly correlated (Table 5). Similar results were obtained by Luo et al. (2010).

**Table 4.** Correlation matrix of macropore range of soil pore-size distribution at the 3–8 cm depth for all the soil samples under different land use methods and soil types

<table>
<thead>
<tr>
<th>Macropore size</th>
<th>Range %</th>
<th>Correlation matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>from</td>
<td>to</td>
</tr>
<tr>
<td>Coarse</td>
<td>0.00</td>
<td>0.52</td>
</tr>
<tr>
<td>Medium</td>
<td>0.53</td>
<td>5.23</td>
</tr>
<tr>
<td>Fine</td>
<td>0.34</td>
<td>4.36</td>
</tr>
<tr>
<td>Very fine</td>
<td>0.40</td>
<td>1.19</td>
</tr>
</tbody>
</table>

*, ** – the least significant difference at $P < 0.05$ and $P < 0.01$, respectively

**Table 5.** Correlation matrix among different macropore characteristics at the 3–8 cm depth under different soil types and land use methods

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Land use method</th>
<th>Properties</th>
<th>Range from to</th>
<th>Correlation matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>volume of</td>
<td>macropores</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>macropores mm$^3$</td>
<td>(diameter) mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>surface area mm$^2$</td>
<td>0.019</td>
<td>137.94</td>
</tr>
<tr>
<td></td>
<td></td>
<td>volume of macropores mm$^3$</td>
<td>0.0003</td>
<td>40.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pore size (diameter) mm</td>
<td>0.076</td>
<td>4.25</td>
</tr>
<tr>
<td>Cambisol</td>
<td>conventional tillage</td>
<td>surface area mm$^2$</td>
<td>0.024</td>
<td>389.92</td>
</tr>
<tr>
<td></td>
<td></td>
<td>volume of macropores mm$^3$</td>
<td>0.0003</td>
<td>67.53</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pore size (diameter) mm</td>
<td>0.075</td>
<td>5.05</td>
</tr>
<tr>
<td></td>
<td>grassland</td>
<td>surface area mm$^2$</td>
<td>0.017</td>
<td>276.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>volume of macropores mm$^3$</td>
<td>0.0002</td>
<td>17.48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pore size (diameter) mm</td>
<td>0.076</td>
<td>3.22</td>
</tr>
<tr>
<td></td>
<td>park</td>
<td>surface area mm$^2$</td>
<td>0.017</td>
<td>196.48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>volume of macropores mm$^3$</td>
<td>0.0003</td>
<td>52.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pore size (diameter) mm</td>
<td>0.075</td>
<td>4.64</td>
</tr>
<tr>
<td></td>
<td>conventional tillage</td>
<td>surface area mm$^2$</td>
<td>0.018</td>
<td>96.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>volume of macropores mm$^3$</td>
<td>0.0002</td>
<td>22.60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pore size (diameter) mm</td>
<td>0.076</td>
<td>3.51</td>
</tr>
<tr>
<td>Retisol</td>
<td>grassland</td>
<td>surface area mm$^2$</td>
<td>0.023</td>
<td>1156.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>volume of macropores mm$^3$</td>
<td>0.0002</td>
<td>312.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pore size (diameter) mm</td>
<td>0.076</td>
<td>8.42</td>
</tr>
<tr>
<td></td>
<td>forest</td>
<td>surface area mm$^2$</td>
<td>0.023</td>
<td>1156.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>volume of macropores mm$^3$</td>
<td>0.0002</td>
<td>312.56</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pore size (diameter) mm</td>
<td>0.076</td>
<td>8.42</td>
</tr>
</tbody>
</table>

*, ** – the least significant difference at $P < 0.05$ and $P < 0.01$, respectively
The relationship between soil $\text{CO}_2$ efflux and volume of macropores. A significant linear trend ($R^2 = 0.65$, $P < 0.05$) reflecting the relationship between $\text{CO}_2$ efflux and volume of macropores was revealed (Fig. 8).

Figure 8. The relationship between soil carbon dioxide ($\text{CO}_2$) efflux and volume of macropores at the 3–8 cm depth under different soil types and land use methods

Soil $\text{CO}_2$ effluxes were affected by soil porosity in both soil types indicating that the soil pore network plays a major role in $\text{CO}_2$ produced by soil respiration. These findings are in agreement with the results published by Mangalassery et al. (2013).

Conclusion

The purpose of the study was to quantify the effect of soil macroporosity, soil temperature and soil water content on carbon dioxide ($\text{CO}_2$) efflux in Cambisol and Retisol, and land use methods: conventional tillage, grassland and park or forest. Average soil surface $\text{CO}_2$ efflux in Retisol was 11% higher than in Cambisol. Both soil types and land use methods had noticeable influences on the network of the macroporosity, surface area and macropore range of soil pore-size distribution. Volumetric water content ($y = 0.0943x - 0.7651$, $R^2 = 0.53$) and macroporosity ($y = 0.1167x - 0.8214$, $R^2 = 0.65$) were dominant factors enhancing $\text{CO}_2$ under different soil types and land use methods. During the whole growing season, the correlation analyses showed poor relationship between soil $\text{CO}_2$ efflux and soil temperature at the 5 cm depth. Topsoil $\text{CO}_2$ efflux under contrasting vegetation cover and management conditions on Cambisol and Retisol was directly related to soil macroporosity and volumetric water content.

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Dirvos makroporingumo, temperatūros ir vendans kiekio įtaka CO₂ emisijai įvairios kilmės skirtingai naudojamuose dirvožemiuose

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Santrauka

Straipsnyje analizuojama dirvožemio makroporų, temperatūros ir vendans kiekio įtaka anglies dioksido (CO₂) emisijai, priklausančia nuo dirvožemio tipo ir žemėnaudos. Momentinė CO₂ emisija nustatyta uždaro gaubto metodu. CO₂ emisija iš dirvožemio viršutinio 0–5 cm sluoksnio tirto (1) tradiciškai dirbtame lauke rudžemyje (RD), (2) daugiametėje pievoje rudžemyje, (3) parke rudžemyje, (4) tradiciškai dirbtame lauke balkšvažemyje (JI), (5) daugiametėje pievoje balkšvažemyje ir (6) miške balkšvažemyje. Ėmė matuoti šešis kartus per augalų vegetaciją, t. y. gegužės, birželio, birželio–augalų dirvojo, rudenio, rudenio–žiemos ir žiemos mėnesius. Dirvožemio makroporingumo įtaka CO₂ emisijai nustatyta tarp CO₂ emisijos ir temperatūros ryšių skirtingams tūriras kilmėms skirtingai naudojamuose dirvožemiuose. Ėmė matuoti šešis kartus per augalų vegetaciją, t. y. gegužės, birželio, birželio–augalų dirvojo, rudenio, rudenio–žiemos ir žiemos mėnesius.