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Short communication

A simple method for in-situ assessment of soil respiration using alkali absorption

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ABSTRACT

Lacking knowledge about the spatial heterogeneity of heterotrophic soil respiration (R_h) hampers the prediction of larger-scale soil CO_2 efflux in patchy landscapes. The aim of this study was to establish a cost-efficient method for the rapid and simultaneous assessment of cumulative heterotrophic soil respiration (CO_2) at different sample spots. For this purpose, we adapted the laboratory-based, fully-automated Respicond VIII respirometer (Respicond) to detect CO_2 emission under field condition, installed the device in two temperate grasslands, and compared the R_h flux data with those obtained using the so-called dynamic chamber method with infrared gas analyzers (IRGA). The results revealed good agreement between both R_h measurements (Slope = 0.89, R^2 = 0.99). We conclude that adapting the Respicond for detection of CO_2 under field conditions is principally feasible, thus providing a new tool for the simultaneous assessment of CO_2 fluxes from different soil ecosystems.

1. Introduction

Heterotrophic microorganisms feeding on soil organic carbon (SOC) release carbon dioxide (CO_2) as an end-product of their metabolic pathway. The amount of respired CO_2 may be used as an indicator of microbial activity and related soil quality (Gil-Sotres et al., 2005); also, it may be used as a measure of soil pollution by heavy metal contamination (Kuperman and Carreiro, 1997), or in the context of global change and the global carbon cycle (Schlesinger and Andrews, 2000; Davidson and Janssens, 2006). However, heterotrophic soil respiration (R_h) is variable in space and time (Saiz et al., 2006; Graf et al., 2012; Herbst et al., 2012), making it tedious to achieve adequate data.

Today, closed (dynamic) chamber techniques (Fang and Moncrieff, 1996; Görres et al., 2015), open-flow chamber techniques (Suh et al., 2006; Yasutake et al., 2014), or gradient methods (Myklebust et al., 2008), operating with infrared gas analyzers (IRGA) are the state-of-the-art for in-situ R_h measurements. However, they are comparatively expensive and elaborate to operate. Particularly, the need to repeat measurements at high spatial resolution increases the number of chambers and IRGAs required and can often make accurate measurements financially prohibitive (Prolingheuer et al., 2010; Graf et al., 2012; Herbst et al., 2012).

The laboratory-based Respicond respirometer VIII (Respicond) measures R_h of up to 96 (soil) samples simultaneously and automatically at a minimum expense (Nordgren, 1988). The principle is based on electrical conductivity changes of a hydroxide solution (KOH) after CO_2 uptake. Chapman (1971) already suggested transferring this method to field conditions, but likely because of emerging IRGA techniques this idea went out of fashion and was not evolved further.

We hypothesize that the laboratory-based Respicond can be adjusted to likewise allow R_h measurements under field conditions. To test this hypothesis, we adapted the Respicond for its use under field conditions (grassland) and compared the results with those obtained from IRGA measurements.

2. Material and methods

2.1. Site description

The methodical tests were performed on two permanent grassland sites, at the Rollesbroich grassland at the TERENO long-term observatories (50°37′26.0″N 6°18′15.0″E; located in North Rhine-Westphalia, Germany; Zacharias et al., 2011), as well as at a private owned grassland, within a distance of approx. 70 km

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(50°42′55.46″N 7°6′22.65″E). As we were not able to measure at both sites simultaneously with the IRGA, measurements switched between sites for different days in the year. Mean annual air temperature and precipitation of the region were 7.7 °C and 1030 mm, and 10.3 and 669 mm, respectively. According to the World Reference Base for Soil Resources (WRB) (IUSS Working Group WRB, 2015), the main soil group of the sites were Cambisols.

2.2. Measurement principle of the Respicond respirometer

The Respicond respirometer VIII (Respicond) (Nordgren Innovations, Sweden) is a fully-automated system for the measurement of soil respiration (CO_2) in the laboratory. Shortly, it consists of two temperature-controlled (ECO RE 630 S, Lauda, Germany) water baths, in which 96 vessels containing soil samples are incubated. The measurement principle of the Respicond relies on electrical conductivity changes of a hydroxide solution after CO_2 uptake, according to Nordgren (1988) (Fig. 1A). CO_2 evolution is computed on the basis of Eq. (1).

$$CO_2 = A \times (C_{fresh} - C_t)/C_{fresh}, \tag{1}$$

where A is the electrical conductivity constant, which dependents on the molarity of hydroxide solution, C_{fresh} is the conductivity of fresh hydroxide solution and C_t is conductivity at time t.

2.3. Adaptation to field conditions

Plastic tubes with a diameter of 7.5 cm, commonly used as joints in pipe works (HTU DN 75, Gebr. Ostendorf Kunststoffe GmbH, Germany) were sawn in halves. They served as soil collars. The screw caps (Fig. 1B (2)) of the standard incubation vessels (Fig. 1(1)) were fitted upside-down into the upper end of the collars (Fig. 1(9)). They were fixed with glue and the rim was additionally sealed with silicone to make it air tight. To allow gas diffusion between soil and vessels, five holes of approx. 1 cm diameter were drilled into the screw caps (Fig. 1(11)). These units were then inserted into the soil (Fig. 1B; Fig. A1 , Appendix in Supplementary material).

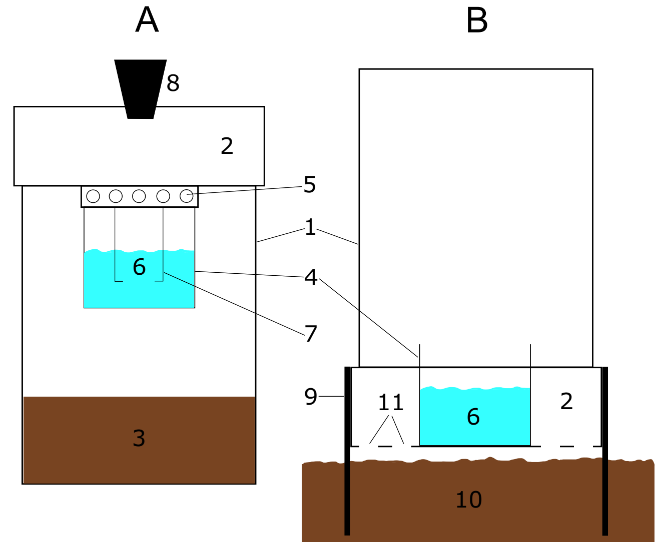

Fig. 1. Basic unit of the Respicond respirometer for respiration measurements in the laboratory (A) and adaptations for field use (B). Both consist of an experimental vessel (1) and a screw cap (2). For laboratory use (A), soil (3) is incubated and CO_2 enters the conductivity cell (4) through holes (5). The conductivity of KOH solution (6) is then measured by platinum electrodes (7). A rubber stopper (8) allows KOH exchange during incubation. For field use (B), the screw cap (2) is attached upside-down to the soil collar (9), which is inserted into the soil (10). Holes in the screw cap (11) allow CO_2 diffusion into the vessel (1) and finally into the KOH solution (6).

2.4. Measurement under field conditions

2.4.1. Respicond field method

The conductivity of the hydroxide solution (KOH) (AppliChem GmbH, Germany) was measured in the laboratory before the start of the experiment (t_0). Then the small jars containing the KOH solution were closed, transported to the field, opened and placed on the soil collars. Subsequently, the vessels were screwed into the collars to create an air-tight headspace (Fig. 1B; Fig. A1, Appendix in Supplementary material). After a given time on the soil collars, the small jars containing the KOH solution were closed and transported back to the laboratory to measure the conductivity again (t_{24}). Cumulative CO_2 emissions were calculated according to Eq. (1). To account for different amounts of CO_2 released, the method was tested for exposure periods of 1–72 h. For a measurement period of up to 1 h, we used a 0.06 M KOH solution as a CO_2 trap, while extended periods were carried out with a 0.6 M KOH solution. By projecting the measurements on the small soil collars to an area of 1 m^2, CO_2 emissions were converted to fluxes for the respective measurement period. Besides the measurement day with the highest fluxes performed in August (n = 2), all other were carried out in tenfold repetition (n = 10), spanning a period from mid-August to the beginning of November.

2.4.2. IRGA method as comparison

Field measurements with the new Respicond method were compared with measurements conducted with an automated soil CO_2 flux chamber system (LI-8100-104, LI-COR Inc., Lincoln, Nebraska, USA) in combination with an infrared gas analyzer (IRGA) (Analyzer Control Unit, LI-8100A, LI-COR Inc., Lincoln, Nebraska, USA). The chamber was set to measure automatically with 20 min resolution using the following settings: (i) dead band, 30 s; (ii) observation length, 120 s; (iii) purge time, 90 s; (iv) observation delay, 60 s; (v) and a flow rate of approximately 1.5 $dm^3\,min^{-1}$. CO_2 fluxes were derived from fitting a linear equation to CO_2 increase (2 s readings) during closure time using the LI-8100 file viewer application software (LI-COR FV8100, LI-COR Inc., version 3.1.0).

2.5. Statistical analyses

Microsoft Excel (Microsoft Corporation) was used for data treatment. SigmaPlot 13 (Systat Software Inc.) was used for generating figures and for comparing IRGA data to the data measured by the new Respicond method by linear regression analysis.

3. Results and discussion

Similar results were obtained when comparing R_h measured with the new Respicond field method and the method involving a dynamic LI-COR chamber system with IRGA detector (Fig. 2). Hence, it is possible to measure R_h under field conditions using the simple Respicond design. This will be of advantage when aiming at inexpensive simultaneous assessment of R_h of a larger, e.g., spatially resolved sample size.

The results outlined in Fig. 2 include significant variations in overall CO_2 release. These variations were partly achieved by varying exposure time (1, 48 and 72 h). With regard to 24 h measurements, the variations in C fluxes ranged from approx. 1 $CO_2\text{-C}\,m^{-2}\,d^{-1}$ (October) to 4.4 $CO_2\text{-C}\,m^{-2}\,d^{-1}$ (August). By comparison, for grassland sites, Byrne and Kiely (2006) reported 3.6 g $CO_2\text{-C}\,m^{-2}\,d^{-1}$ as an annual mean iR_h value in Ireland, and