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Comparison of chamber methods for measuring soil respiration under field and laboratory conditions

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Despite global significance of soil respiration as well as the dedication of considerable scientific resources to its study over the last several decades, we have only a limited understanding of the magnitude of soil respiration within and across ecosystems and the factors controlling soil respiration. A contributing factor to our limited understanding of soil respiration is a lack of consensus on methods for measuring soil respiration (Rustad et al., 2000). Systematic biases between different measurement methodologies introduce considerable unknowns into the interpretation of the literature on soil respiration and in estimating the magnitude of soil respiration within and across ecosystems. Therefore a comparison among methods is essential if we are to develop confidence with the measurement of this important soil respiration. Problems of spatial and temporal scale also need to be addressed, particularly the problem of scaling-up results from small chambers to the stand or ecosystem level, let along the regional or global level (Rustad et al., 2000).

In order to provide sufficient insight into the use of chamber methods for measuring soil respiration, the main objective of the present study was to compare chamber methods for measuring soil respiration under field and laboratory conditions. A second objective was to determine the spatial variability of soil respiration and the number of the sampling points required to get a representative value of soil respiration within an ecosystem.

The objectives of the present study were to compare the static alkali absorption (AA) and dynamic closed chamber (DC) methods for measuring soil respiration, and to evaluate the effects of methodological differences on estimating annual mean soil respiration rate in a natural forest. For the AA method, we used Kirita (1971)'s method using an alkali-soaked sponge disc that covers nearly the same area as that covered by a chamber. For the DC method, we used both the LI-6200 system (DC-62 method) and the newer LI-6400 system (DC-64 method) (LI-COR, Lincoln, NE). Comparative measurements were conducted on five occasions during the study period (November 1998 to October 1999) at a *Quercus serrata* forest in Japan. Daily mean soil respiration rates obtained by the AA, DC-62 and DC-64 methods for a 24-hour period were in the ranges 205~578, 147~629 and 165~734 mg CO_2 m^{-2} h^{-1}, respectively. The daily mean soil respiration rates obtained by the AA method were 79~128% of those obtained by the DC-64 method. When the daily mean soil respiration rate obtained by the DC-64 method was below 300 mg CO_2 m^{-2} h^{-1}, the daily mean soil respiration rate obtained by the AA method was an average of 26% higher than that obtained by the DC-64 method. When the daily mean soil respiration rate obtained by the DC-64 method was above 300 mg CO_2 m^{-2} h^{-1}, the daily mean soil respiration rate obtained by the AA method was an average of 19% lower than that obtained by the DC-64 method. However, at the present site, there was a little difference between the two methods as for estimating annual mean soil respiration rate, and therefore the AA method improved by Kirita (1971) is suggested to be a useful method for estimating annual mean soil respiration in the forest. The daily mean soil respiration rates obtained by the DC-62 method were systematically 10~24% lower (an average of 15% lower) than those obtained with the DC-64 method, and the annual mean rate was lower than that estimated by the AA method.

The objective of the present study was to evaluate three commonly used methods using known effluxes from the surface of a simulated soil. The three methods tested in present study were the static alkali absorption (AA), open flow chamber (OF), and dynamic closed chamber (DC-64; LI-6400 system) methods. Our reference method for determining the known flux of CO_2 from a laboratory apparatus (Nay et al. 1994) was based on independent measurements of the soil CO_2 diffusivity and the CO_2 concentration gradient, and the use of Fick's law of diffusion. Comparative measurements were conducted on eleven occasions and eleven different CO_2 efflux rates ranging from 0 to 1000 mg CO_2 m^{-2} h^{-1} were achieved in trials lasting 24 hours. Compared to the reference method, both the AA and OF methods exhibited biases. The AA method greatly overestimated the zero efflux, and overestimated the effluxes below 300 mg CO_2 m^{-2} h^{-1} by an average of 76% and the effluxes above 300 mg CO_2 m^{-2} h^{-1} by an average of 5%. The OF method slightly underestimated the effluxes by an average of 6% when the relatively proper flow rates corresponding to the particular CO_2 effluxes were determined. However, even as both flow meters at the inlet and the outlet of chamber were maintained at the nearly same rates, the flux values obtained by the OF method were highly sensitive to the flow rate through the chamber and significantly larger biases resulted from small error (as small as 0.1 L min^{-1}) in determining flow rate. Therefore, for reasonable measurement by the OF method, some trial may be required to determine the best relationship among flow rate, the capacity of pump, chamber volume, and flux scales. There were not very differences between the reference rates and the rates obtained by the DC-64 method, and these results indicate that the DC-64 method may give accurate results for measuring soil respiration.

The objective of this study was to determine the spatial variability of soil respiration and the number of the sampling points required to get a representative value of soil respiration within an ecosystem. In late August 2000, two measurements of soil respiration were conducted at a larch (*Larix kaempferi*) plantation in Hokkaido, Japan, with the static alkali absorption method (AA method) improved by Kirita (1971). The spatial variability of soil respiration rates among 50 sampling points within a 30 m×30 m plot, was described by the coefficient of variation (CV) of each series of measurements. The average CV was 28%. The average number of sampling points required to estimate soil respiration within 10% and 20% of its actual mean, at the 95% probability level, was estimated to be 30 and 8, respectively. Even soil respiration rates obtained by the improved AA method might be underestimated at high CO_2 efflux. Taking this point into consideration, the actual magnitude of the spatial variability of soil respiration, and consequently the number of sampling points required would be larger than the values given above. Also, the number of sampling points may depend on the area covered by a chamber. The chamber used in the present study has an area of 125 cm^2. Larger chambers (e.g. the OF chamber with area of 346 cm^2) may require fewer sampling points and smaller chambers (e.g. the DC chamber with area of 80 cm^2) may require more. Soil temperature and moisture content did not contribute to the spatial variability of soil respiration in the present site, suggesting that these two factors have a greater influence on the temporal variability of soil respiration than on the spatial variability of soil respiration.

The present study verified that the DC-64 method gives accurate result for measuring soil respiration in the laboratory, and indicates the probability of the DC-64 method as a reference method for measuring soil respiration in the field.

Soil respiration rates estimated by the DC-62 method were consistently an average of 15% lower than those estimated by the DC-64 method, and it is possible to calibrate the data obtained by the LI-6200 system to those obtained by the LI-6400 system.

The AA method of Kirita had sufficient ability to measure effluxes ranging 300~1000 mg CO_2 m^{-2} h^{-1} when any biological disturbances by the chamber were not existing. In the temperate forest where monthly mean soil respiration rates were estimated in the range 109~838 mg CO_2 m^{-2} h^{-1} by the DC-64 method, estimations of annual mean soil respiration by the AA and DC-64 methods were not very different. These results indicate the availability of the AA method modified by Kirita as a method for estimating annual mean soil respiration in the forest. However, the Q_{10} value obtained by the AA method might be underestimated, as a consequence of the biases of the AA method.

The OF method slightly underestimated effluxes ranging 0~1000 mg CO_2 m^{-2} h^{-1} by an average of 6%. However, the flux values obtained by the OF method were highly sensitive to the flow rate and significantly larger biases resulted from small error in determining flow rate. More studies are needed to more clearly determine the best relationship among flow rate, the capacity of pump, chamber volume, and flux scales. And also additional experiment is needed to detect the potential pressure difference using a more accurate flow meter with a micromanometer.