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Short communication

Gas pooling: A sampling technique to overcome spatial heterogeneity of soil carbon dioxide and nitrous oxide fluxes

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ABSTRACT

Small-scale spatial variability in soil carbon dioxide (CO_2) and nitrous oxide (N_2O) fluxes poses serious challenges to the experimental design, and number of gas samples needed to provide a reliable estimate of flux usually exceeds analytical capacities. We pooled gas samples –analogously to soil pooling – to overcome this challenge. Our sample pooling technique collects a composite gas sample from several chambers instead of the conventional practise of analyzing samples from chambers individually, thus reducing numbers of gas samples. The method was verified to be reasonably accurate in forest, grassland and agricultural fields over a four week measurement campaign. Pooling technique results differed by 2–8% for CO_2 and by 3–4% for N_2O when compared to individual chamber means. That shows pooling of gas samples across individual static chambers is an acceptable approach to integrate spatial heterogeneity.

Practical methods are needed to quantify soil CO_2 and N_2O fluxes in order to better understand magnitudes, spatial and temporal variability of soil-atmosphere CO_2 and N_2O exchange. This information is needed to develop improved management practices aiming towards lower CO_2 and N_2O emissions. Static chambers are the most commonly used approach for measuring soil greenhouse gas (GHG) fluxes (Grahammer et al., 1991; Livingston and Hutchinson, 1995; Smith et al., 1995) because relatively low cost, simple operation, and portability (Butterbach-Bahl et al., 2011; Denmead, 2008). Furthermore, the simple technique and deployment protocol can be adapted to a wide range of ecosystems and experimental designs (Rochette, 2011).

The basic principle of static chambers measurements is that a number of gas samples (three to six) are taken over a period of time from the headspace of a gas-tight chamber enclosing the soil surface. GHG fluxes are calculated from the rate of change in the headspace gas concentration over time.

Soil fluxes of CO_2 and N_2O vary significantly over space and time driven by microbiological processes, environmental conditions, heterogeneity of soil properties and spatial variation in available nutrients and root distribution (Butterbach-Bahl et al., 2011; Davidson et al., 2000; Verchot et al., 1999). Specifically, small-scale spatial variability – within a few meters – commonly exceeds 100% (Parkin and Venterea, 2010). Thus, replicated chamber measurements on sites investigated is required to achieve robust representative emission rates. Furthermore, when investigating CO_2 and N_2O fluxes in landscapes with a mosaic of land uses and land covers, the total number of samples needed to provide a reliable flux estimate quickly exceeds analytical capacities.

Pooling is accepted and widely used for soil sampling, but it was so far not tested as a method to overcome the limitations imposed by time-consuming (and hence cost intensive) analytics

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and procedures in CO_2 and N_2O measurements. Here we propose gas sample pooling to reduce the number of gas samples required while maintaining the reliability of the estimated CO_2 and N_2O flux.

We selected three different experimental sites for measuring N_2O and CO_2 soil-atmosphere fluxes with five chambers each over a four-week period: a forest (a 30-years old *Eucalyptus* plantation) a non-grazed grassland and a kale (*Brassica oleracea* L.) cropland. Each site had at least an area of 0.25 ha. We compared the emission rates obtained with the gas sample pooling technique (Fig. 1) with the mean rates of each observation date calculated from sampling the five individual chambers following the traditional method. The number of chambers was chosen in order to allow one operator to conduct the gas sampling within chamber closure period (40 min).

The study sites were located on the Maseno University Campus (Kenya) (0°, 34° 36′E). The experiment was conducted from 29 October to 29 November in 2012. Site characteristics are presented in Table 1. At each site, five 35 by 25 cm^2 PVC frames (collars) were inserted prior to the first measurement and remained in place throughout the experimental period. For CO_2 and N_2O measurements, a PVC chamber (12 cm high), equipped with a fan, a non-forced vent and a sampling port was affixed to the frame by metal clamps and a rubber sealing between frame and chamber to assure air-tight seal.

For individual chamber measurements 50 ml gas sample was taken from the chamber headspace with a gas tight syringe through a stopcock valve at 10 min intervals (0, 10, 20, 30, and 40 min after chamber closure). If the use of a fan is not possible, an extra syringe should be used to carefully pump several times before taking the gas sample to obtain homogenous mixing of the headspace air.

For the gas pooling technique, a 10 ml sample was collected from each of the five chambers with the same syringe at each time interval equaling 50 ml in total (Fig. 1a). The 50 ml gas samples were then immediately transferred into 10 ml sealed glass vials (Fig. 1b) and analyzed by gas chromatography (^{63}Ni-Electron capture detector for N_2O and Flame ionization detector equipped with a methanizer for CO_2). Detailed information about the analytical procedure can be found in Gauder et al. (2012) Flux rates of N_2O and CO_2 were calculated from the linear change in gas concentrations in the chamber headspace with time.

It was our aim to test the applicability of the gas pooling technique across a range of N_2O and CO_2 emission rates. Therefore, on November 5th, cropland and grassland experimental sites were fertilized with granular urea dissolved in water at a rate of 100 kg N ha^{-1} simulating a 10 mm rainfall event.

Results from individual chamber measurements and gas sample pooling technique highly agreed for CO_2 measurements, capturing temporal variations of fluxes over the observation period (Fig. 2).

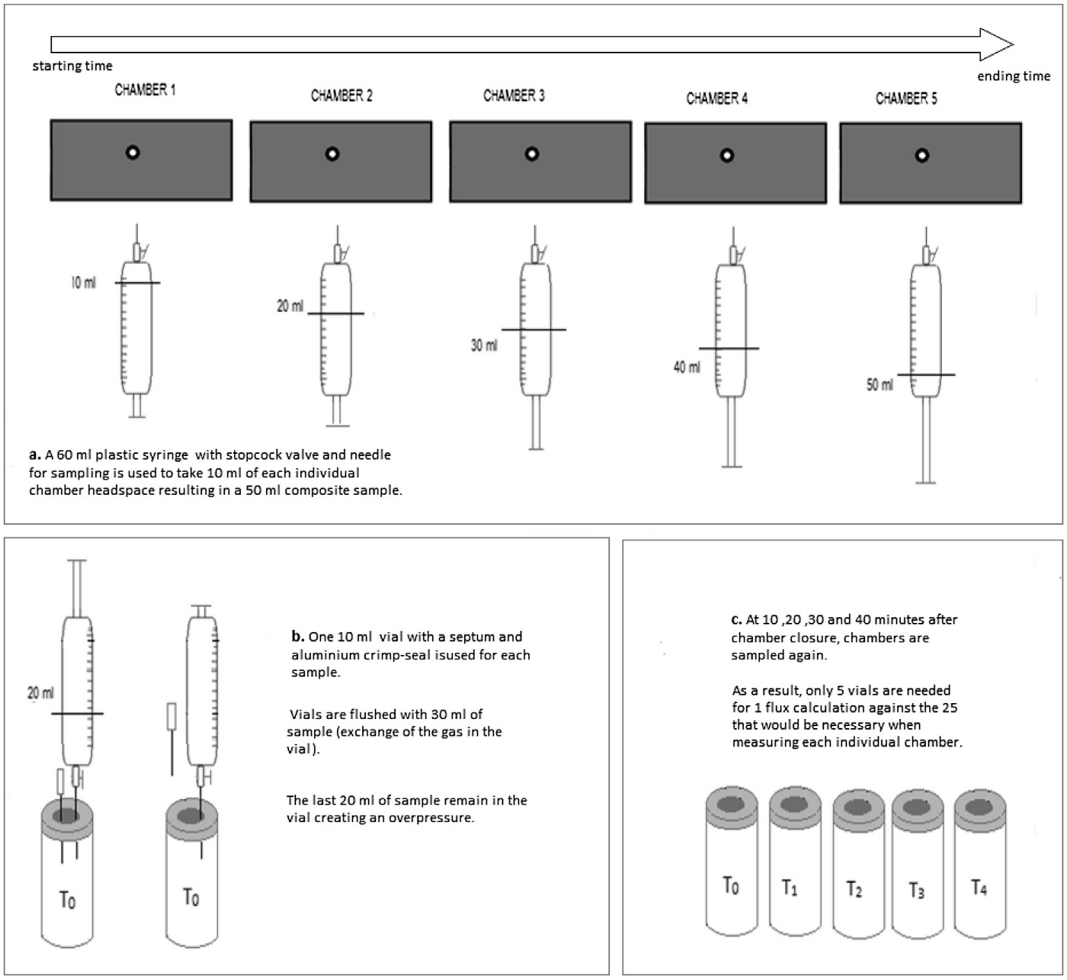

Fig. 1. Concept of gas sample pooling.