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Carbon transfer, partitioning and residence time in the plant-soil system: a comparison of two 13C-CO_2 labelling techniques

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13C-CO_2 labelling is a powerful tool to study the carbon (C) dynamics in plant-soil systems, whereby various approaches have been applied, differing in the duration of label exposure, the applied label strength and the sampling intervals. We made a direct comparison of the two main 13C-CO_2 labelling techniques - pulse and continuous labelling - and evaluated if different approaches yield the same results regarding the C transfer time, C partitioning and the C residence time in different plant-soil compartments.

We conducted a pulse labelling (exposure to 99 atom% 13C-CO_2 for three hours, traced for eight days) and a continuous labelling (exposure to 10 atom% 13C-CO_2, traced for 14 days) on identical plant-soil systems (Populus deltoides x nigra, Cambisol soil) and under controlled environmental conditions. The plant-soil systems were destructively harvested at five sampling dates, and the soil CO_2 efflux was sampled throughout the experiments. The 13C distribution into leaves, petioles, stems, cuttings, roots, soil, microbial biomass and soil respiration was analysed and wee applied exponential (pulse labelling) and logistic (continuous labelling) functions to model the C dynamics.

Our results confirm that pulse labelling is best suited to assess the minimum C transfer time, while continuous labelling can be applied to assess the C transfer through a compartment, including short-term storage pools. Both experiments yielded the same C partitioning patterns at the specific sampling days, however, the time of sampling was crucial. For example the results of belowground C partitioning were consistent only after eight days of labelling. The C mean residence times estimated by the rate constant of the exponential and logistic function were largely different for the two techniques, mostly due to the strong model assumptions (e.g. steady state).

Pulse and continuous labelling techniques are both well suited to assess C cycling. With pulse labelling, the dynamics of fresh assimilates can be traced, whereas the continuous labelling gives a more integrated result of C cycling, due to the homogeneous labelling of C pools and fluxes. The logistic model applied here, has the potential to assess different parameters of C cycling independent on the sampling date and with no disputable assumptions.