Geophysical Research Abstracts,
Vol. 11, EGU2009-7184-1, 2009
EGU General Assembly 2009
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Time lag between photosynthesis and CO2 efflux from soil

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Important part of CO2 efflux from planted soils is root-derived CO2, meaning that it originates directly and indirectly from roots: directly from root respiration, and indirectly from respiration of rhizosphere microorganisms decomposing organic substances released by roots into the soil (rhizodeposits). Recent studies have shown that apart of well studied effect of soil temperature and soil water content, the C supply of assimilates from photosynthetically active plant organs have a significant effect on the root-derived CO2. In fact, the effect of photosynthesis on root-derived CO2 is often masked by temperature because root biomass typically peaks in summer. However, roots can only respire the C that was allocated belowground, and so the effect of temperature on root respiration is likely to be constrained by photosynthesis. If models of soil respiration are to incorporate photosynthetic C inputs it is necessary to understand how these two fluxes are coupled and what are the factors affecting the time lag between C uptake and its following respiration by roots and associated microorganisms.

We reviewed literature and own studies relevant for estimation of the delay of C assimilation by photosynthesis and CO2 efflux from soil. The most of the studies were based on pulse labeling of annual plants in the atmosphere with 14CO2 or 13CO2 and subsequent chase of 14C or 13C in the CO2 efflux from soil. We analyzed the dynamics of the CO2 efflux curves and evaluated 3 parameters: 1) the first appearance of labeled CO2 from soil, 2) maximum of labeled CO2, and 3) disappearance of the labeled CO2 from the total CO2 efflux from soil.

Numerous studies showed that newly assimilated C cycles quickly within the ecosystem, being found in root respiration already some minutes after its assimilation. Reported time lags in situ and laboratory experiments varied from minutes to days. For annual and perennial grasses the first appearance of labeled CO2 from soil was measured within one hour after the labeling. The time lag between photosynthesis and the maximum of labeled CO2 from soil was reached during the first day nearly after 12 h. However, strong contribution of labeled CO2 to the total efflux from soil was finished within 2-5 days.

The longer duration of the time lag obtained for tree species (2-4 days) in confront with grasses, suggests that a plant height and thus a phloem pathway length could determine the range in which the delay between the photosynthetic C uptake and its following respiration varies. Inside this limits the speed and the quantity of the translocated C to belowground is more likely determined by plant growing stage.

We conclude that root-derived CO2 efflux from soil originates mainly from the organic substances assimilated few hours (for grasses) up to few days (for trees) at the canopy level. Therefore, any changes of climatic drivers strongly affecting photosynthesis will be reflected in the root-derived CO2 and also in total CO2 efflux from soil. Therefore, not the soil temperature (as commonly accepted), but photosynthesis intensity should be considered while modeling of the total CO2 efflux from soils. This is especially true for the ecosystems where root derived CO2 accounts for a significant part of total CO2 efflux from soil.