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The ‘overflow tap’ theory: linking GPP to forest soil carbon dynamics and the mycorrhizal component

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Quantifying soil organic carbon (SOC) dynamics accurately is crucial to underpin better predictions of future climate change feedbacks within the atmosphere-vegetation-soil system. Measuring the components of ecosystem carbon fluxes has become a central point of the research focus during the last decade, not least because of the large SOC stocks, potentially vulnerable to climate change. However, our basic understanding of the composition and environmental responses of the soil CO2 efflux is still under debate and limited by the available field methodologies. For example, only recently did we separate successfully root (R), mycorrhizal fungal (F) and soil animal/microbial (H) respiration based on a mesh-bag/collar methodology and described their unique environmental responses. Yet it might be these differences which are crucial for understanding C-cycle feedbacks and observed limitations in plant biomass increase under elevated carbon dioxide (e.g. FACE) studies. It is becoming clear that these flux components and their environmental responses must be incorporated in models that link but also treat the heterotrophic and autotrophic fluxes separately. However, owing to a scarcity of experimental data, separation of fluxes and environmental drivers has been ignored in current models. We are now in a position to parameterize realistic soil C turnover models that include both, decomposition and plant-derived fluxes. Such models will allow (1) a direct comparison of model output to field data for all flux components, (2) include the potential to link plant C allocation to the rhizosphere with increased decomposition activity through soil C priming, and (3) to explore the potential of plant biomass C sequestration limitations under increased C assimilation. These mechanisms are fundamental in describing the stability of future SOC stocks due to elevated temperatures and carbon dioxide, altering SOC decomposition directly and indirectly through changes in plant productivity. The work presented here focuses on three critical areas:

(1) We present annual fluxes at hourly intervals for the three soil CO2 efflux components (R, F and H) from a 75 year-old deciduous oak forest in SE England. We investigate the individual environmental responses of the three flux components, and compare them to soil decomposition modelled by CENTURY and its latest version (i.e. DAYCENT), which separately models root-derived respiration in addition to the soil decomposition output.
(2) Using estimates of gross primary productivity (GPP) based on eddy covariance measurements from the same site, we explore linkages between GPP and soil respiration component fluxes using basic regression and wavelet analyses. We show a distinctly different time lag signal between GPP and root vs. mycorrhizal fungal respiration. We then discuss how models might need to be improved to accurately predict total soil CO2 efflux, including root-derived respiration.
(3) We finally discuss the ‘overflow tap’ theory, that during periods of high assimilation (e.g. optimum environmental conditions or elevated CO2) surplus non-structural C is allocated belowground to the mycorrhizal network; this additional C could then be used and released by the associated fungal partners, causing soil priming through stimulating decomposition.