Biogeosciences, 9, 1823–1825, 2012
www.biogeosciences.net/9/1823/2012/
doi:10.5194/bg-9-1823-2012

Biogeosciences

Preface

"Biotic interactions and biogeochemical processes in the soil environment"

J.-A. Subke[1], M. S. Carbone[2], M. Khomik[3], P. Stoy[4], and M. Bahn[5]

[1]School of Natural Sciences, Biological and Environmental Sciences, University of Stirling, Stirling FK9 4LA, UK
[2]National Center for Ecological Analysis and Synthesis, Santa Barbara, CA 93101, USA
[3]Biogeochemical Model-Data Integration Group, Max Planck Institute for Biogeochemistry, Jena, Germany
[4]Dept. of Land Resources and Environmental Sciences, Montana State University, Bozeman, MT 59717, USA
[5]Institute of Ecology, University of Innsbruck, Sternwartestr. 15, 6020 Innsbruck, Austria

Correspondence to: J.-A. Subke (jens-arne.subke@stir.ac.uk)

Soils play a key role in the terrestrial carbon (C) cycle by storing and emitting large quantities of C. The impact of abiotic conditions (mainly soil temperature and moisture) on soil C turnover is well documented, but unravelling the influence of these drivers across temporal and spatial scales remains an important challenge. Biotic factors, such as microbial abundance and diversity, macro-faunal food webs and below-ground plant (i.e. root) biomass and diversity, play an important role in controlling soil C storage and emission, but remain under-investigated. To better understand the soil processes underlying terrestrial C cycling, the interactions between plants (autotrophs) and soil organisms (heterotrophs) need to be addressed more explicitly and integrated with short- and long-term effects of abiotic drivers.

This special issue presents recent advances in field, laboratory, and modelling studies on soil C dynamics, with a particular emphasis on those aiming to resolve abiotic and biotic influences. The manuscripts highlight three areas of investigation that we suggest are central to current and future progress in ecosystem C dynamic research: (1) novel interpretations of abiotic controls on soil CO_2 efflux, (2) legacy effects of abiotic drivers of soil C dynamics, and (3) the interaction between plant C dynamics and soil biological processes.

1 Abiotic control of soil CO_2 efflux

Temperature is one of the main drivers of soil C turnover and respiration, but the ways in which soil CO_2 efflux responds to changes in ambient temperature remain under debate (Davidson et al., 2006, Subke and Bahn, 2010). The response of CO_2 efflux to changes in temperature amplitude, rather than changes in mean temperature, has received little attention, and Sierra et al. (2011) demonstrate temperature sensitivity of soil CO_2 efflux in response to temperature amplitude in different biomes. Present temperature responses in global C models are likely to include a bias in predictions where only mean temperature changes, but not shifts in temperature amplitude, are considered.

Combined temperature and moisture effects on soil C dynamics are highlighted by the papers of Niinistö et al. (2011) and Nagy et al. (2011). Despite a dominant control of temperature on soil CO_2 efflux in a Finnish Scots pine forest, Niinistö et al. (2011) show that summer drought has considerable impacts on short-term fluxes. During mid-summer when soil CO_2 efflux is at its seasonal peak, little or no temperature response of soil CO_2 efflux was observed, which may relate to seasonal changes in below-ground autotrophic substrate supply to roots and associated microbes.

Using the flux-gradient technique, Nagy et al. (2011) show the profound influence that precipitation events have on apparent ecosystem respiration measurements by altering soil porosity in the short-term. As soil profile measurements are increasingly used to estimate soil CO_2 efflux (e.g. Daly et al.,

Published by Copernicus Publications on behalf of the European Geosciences Union.

2009), there is a need to combine knowledge from soil diffusion modelling with ecophysiological data in order to interpret profile measurements correctly, and enable appropriate quantification of diffusion in the field (Risk et al., 2008).

2 Legacy effects of abiotic drivers

Keiser et al. (2011) provide evidence that the effect of resource history on soil microbial community function is maintained across time. Their findings suggest that microbial dynamics should not be omitted from models of ecosystem processes, if we are to predict reliably global change effects on biogeochemical cycles.

We still lack full mechanistic understanding of how temperature history affects current and future decomposition rate of litter and soil organic matter. Wetterstedt and Ågren (2011) used data from a needle litter incubation experiment to compare temperature responses of litter qualities to temperature-dependent decomposer efficiency. Their results suggests that, when evaluating effects of temperature changes on soil organic matter stability, it may be important to consider microbial efficiency, or changing substrate composition, rather than the temperature sensitivity coupled to substrate quality.

3 Interaction of plant C dynamics and soil biological processes

Transfer of C from plants to soil via root exudations has been highlighted as a critical contribution to soil C budgets. Apart from the direct influence of plant C allocation on autotrophic soil CO_2 efflux components, a link to decomposition via soil C priming has been established in recent years (Kuzyakov, 2010), and highlights the need to better understand the linkages between vegetation and soil.

Heinemeyer et al. (2011) measured autotrophic and heterotrophic components of soil respiration in a deciduous forest, and applied spectral analysis to examine connections between plant C assimilation and the dynamics of different soil CO_2 efflux components. Uniquely, the authors quantify the soil CO_2 efflux attributed to ectomycorrhizal fungi with field manipulations. Roots and mycorrhizas both respond to diurnal variability in gross primary productivity (GPP), but differences in the correlation with GPP over longer time scales challenge the idea of considering roots and mycorrhizas together as the "mycorrhizosphere".

Metcalfe et al. (2011) take a wider look at literature results relating to the role of vegetation in soil C dynamics. Their review suggests that individual plant taxa may have a more profound impact on soil C dynamics than diversity of plant taxa. Metcalfe et al. (2011) conclude that (1) changes in C allocation to the rhizosphere, (2) indirect effect via changes in litter quantity and quality, and (3) shifts in microclimate following changes in vegetation will dominate soil CO_2 efflux changes compared to direct influences of climatic drivers.

De Deyn et al. (2011) demonstrate the rapid and close connection between plant C assimilation and C flow to microbial communities in grasslands, but show differences in plant allocation and hence the fate of assimilated C among different plant taxa. Therefore, shifts in species composition due to changes in environmental factors or land management may impact C assimilation and turnover in grassland soils.

Finally, while most studies look at the dynamics of C fluxes or soil C stocks independently, Kuzyakov (2011) demonstrates the power of incorporating both, advancing our understanding of soil dynamics and resolving the disagreements in the mean residence times of soil organic carbon derived from pool-based and flux-based studies.

4 Conclusions

The contributions to this special issue indicate that: (1) the ways in which temperature and moisture responses of soil CO_2 efflux are obtained and implemented in models remain areas that require more research; (2) legacy effects of temperature and resource history impact microbial functioning and soil C turnover at different timescales; (3) quantifying plant below-ground allocation is key to a better understanding of below-ground C dynamics; (4) the effects of plant species composition and plant traits on below-ground processes require increased attention in future studies; and (5) future studies should focus on integrating soil C dynamics across different time scales, from CO_2 fluxes to C stocks changes.

Acknowledgements. MK acknowledges support by the ERC starting grant QUASOM (ERC-2007-StG-208516). MSC was supported by the NOAA Climate & Global Change Postdoctoral Fellowship Program administered by UCAR, and the NCEAS Postdoctoral Fellowship funded by NSF Grant #EF-0553768. PCS acknowledges funding from the Marie Curie European Incoming International Fellowship (project #237348, TSURF), the National Science Foundation (DBI #1021095), and Montana State University.

References

Daly, E., Palmroth, S., Stoy, P. C., Siqueira, M. B. S., Oishi, A. C., Juang, J.-Y., Oren, R., Porporato, A., and Katul, G. G.: The effects of elevated atmospheric CO_2 and nitrogen amendments on subsurface CO_2 production and concentration dynamics in a maturing pine forest. Biogeochemistry, 94, 271–287, 2009.

Davidson, E. A., Janssens, I. A., and Luo, Y. Q.: On the variability of respiration in terrestrial ecosystems: moving beyond Q(10), Global Change Biol, 12, 154–164, 2006.

De Deyn, G. B., Quirk, H., Oakley, S., Ostle, N., and Bardgett, R. D.: Rapid transfer of photosynthetic carbon through the plant-soil system in differently managed species-rich grasslands, Biogeosciences, 8, 1131–1139, doi:10.5194/bg-8-1131-2011, 2011.

Heinemeyer, A., Wilkinson, M., Vargas, R., Subke, J.-A., Casella, E., Morison, J. I. L., and Ineson, P.: Exploring the "overflow tap" theory: linking forest soil CO_2 fluxes and individual mycorrhizosphere components to photosynthesis, Biogeosciences, 9, 79–95, doi:10.5194/bg-9-79-2012, 2012.

Keiser, A. D., Strickland, M. S., Fierer, N., and Bradford, M. A.: The effect of resource history on the functioning of soil microbial communities is maintained across time, Biogeosciences, 8, 1477–1486, doi:10.5194/bg-8-1477-2011, 2011.

Kuzyakov, Y.: Priming effects: Interactions between living and dead organic matter, Soil Biol. Biochem., 42, 1363–1371, 2010.

Kuzyakov, Y.: How to link soil C pools with CO_2 fluxes?, Biogeosciences, 8, 1523–1537, doi:10.5194/bg-8-1523-2011, 2011.

Metcalfe, D. B., Fisher, R. A., and Wardle, D. A.: Plant communities as drivers of soil respiration: pathways, mechanisms, and significance for global change, Biogeosciences, 8, 2047–2061, doi:10.5194/bg-8-2047-2011, 2011.

Nagy, Z., Pintér, K., Pavelka, M., Darenová, E., and Balogh, J.: Carbon fluxes of surfaces vs. ecosystems: advantages of measuring eddy covariance and soil respiration simultaneously in dry grassland ecosystems, Biogeosciences, 8, 2523–2534, doi:10.5194/bg-8-2523-2011, 2011.

Niinistö, S. M., Kellomäki, S., and Silvola, J.: Seasonality in a boreal forest ecosystem affects the use of soil temperature and moisture as predictors of soil CO_2 efflux, Biogeosciences, 8, 3169–3186, doi:10.5194/bg-8-3169-2011, 2011.

Risk, D., Kellman, L., and Beltrami, H.: A new method for in situ soil gas diffusivity measurement and applications in the monitoring of subsurface CO_2 production, J. Geophys. Res., 113, G02018, doi:10.1029/2007JG000445, 2008.

Sierra, C. A., Harmon, M. E., Thomann, E., Perakis, S. S., and Loescher, H. W.: Amplification and dampening of soil respiration by changes in temperature variability, Biogeosciences, 8, 951–961, doi:10.5194/bg-8-951-2011, 2011.

Subke, J. A. and Bahn, M.: On the "temperature sensitivity" of soil respiration: Can we use the immeasurable to predict the unknown?, Soil. Biol. Biochem., 42, 1653–1656, 2010.

Wetterstedt, J. Å. M. and Ågren, G. I.: Quality or decomposer efficiency - which is most important in the temperature response of litter decomposition? A modelling study using the GLUE methodology, Biogeosciences, 8, 477–487, doi:10.5194/bg-8-477-2011, 2011.