

23rd New Phytologist Symposium: Carbon cycling in tropical ecosystems, Guangzhou, China, November 2009

The 23rd New Phytologist Symposium provided a valuable opportunity for interactions among carbon-cycle researchers working in China and their international counterparts. The 4-day meeting took place just 2 weeks before the COP15 (UN-Climate Change Conference) in Copenhagen and provided an excellent insight into some of the discussions anticipated at that conference. Over 120 delegates from China, other Asian countries, Europe, the Americas and several Pacific Rim countries participated in the meeting, enabling experiences and examples of tropical carbon-cycle research to be shared from around the world.

The meeting began with welcomes from Hai Ren and Guoyi Zhou (South China Botanical Garden), Xiao Yang (Guangzhou Association for Science and Technology), and Ian Alexander (New Phytologist Trust). The first oral presentation was given by Zhu Hua (Xishuangbanna Tropical Botanical Garden, China) who provided a comprehensive overview of the rich botanical communities and regional affiliations of tropical China (Zhu and Roos, 2004). Colin Prentice (University of Bristol, U.K) immediately moved to the global level, using models to explore how the carbon cycle varied with climate and vegetation changes through the most recent glacial/interglacial transition. Feedbacks between atmospheric CO₂ concentrations and net primary productivity (NPP) were shown to be critical for reconstructing vegetation dynamics and C cycling following the last ice age. These results emphasize the importance of atmospheric CO₂ concentration in partially regulating rates of NPP (*i.e.* CO₂ fertilization effect), which has broad implications for predicting how forests will respond to increasing atmospheric CO₂.

Carbon pools and fluxes

Jingyun Fang (Peking University, China) gave a somewhat controversial presentation highlighting a substantial disparity between FAO estimates of global tropical forest carbon stocks with models based on remotely sensed NDVI, building upon his group's success in analyzing China's forest biomass in this way (*e.g.*, Piao *et al.* 2005; 2009). This topic generated lively discussion focused on cautions necessary when using remotely sensed data and the accessible FAO datasets for studying ecosystem C dynamics. Sandra Brown (Winrock International) advised that forest area and biomass estimates should be evaluated on a country by country basis according to their data acquisition, analysis and reporting procedures. In addition, the group agreed that there is a pressing need for more accurate C assessments for tropical forests worldwide, particularly for underrepresented regions such as equatorial Africa. Large scale projects such as the Large-Scale Biosphere-Atmosphere Experiment in Amazonia (<http://www.lbaeco.org/lbaeco/>) and Amazon Forest Inventory Network (<http://www.geog.leeds.ac.uk/projects/rainfor/>) are well developed in South America, and are providing the first comprehensive 'bottom up' and 'top down' estimates of C cycling in tropical rainforests. These types of projects set an impressive example of

what type of research is needed globally to better understand C cycling in tropical forests.

Yadvinder Malhi (University of Oxford, U.K.) continued the session on carbon pools and fluxes with an examination of forest carbon allocation and fluxes along fertility, disturbance, and elevation gradients in the Amazon. His group has found that plant carbon allocation is affected more strongly by disturbance than by site fertility, and that the proportion of plant carbon allocation above- and belowground are constant along the elevation gradient. Furthermore, heterotrophic respiration decreases at sites with lower temperature while autotrophic respiration does not, indicating a decoupling of photosynthesis and decomposition (Aragão *et al.* 2009; Malhi *et al.* 2009). Although the two processes are largely driven by temperature and moisture, we may expect distinct autotrophic and heterotrophic responses to climate change.

The Amazon basin was traditionally thought to be a relatively stable environment. However, recent studies have indicated that in fact the Amazon is prone to periodic drought and fire disturbances which drive important changes in C cycling. Pierre Friedlingstein (Laboratoire des Sciences du Climat et de l'Environnement, CEA-Saclay, France) presented new models linking remotely sensed productivity in Amazonia to water availability, focusing on the 2005 El Niño drought there (Le Quéré *et al.* 2009; Lewis, 2009). This work highlights the challenges involved when using dynamic global vegetation models to predict C cycling responses to elevated atmospheric CO₂, due to shifting precipitation patterns anticipated from natural cycles and global climate change.

In addition to elevated atmospheric CO₂, increasing N deposition in tropical regions is an important consequence of industrialization, and could interact strongly with C cycling. Guoyi Zhou (South China Botanical Garden, China) described nitrogen manipulations at Dinghushan forest in SE China (field trip destination later in the meeting) suggesting that phosphorus can limit forest productivity even when temperature, moisture and nitrogen are readily available. As old-growth forests with similar species composition to Dinghushan exist across a nitrogen-deposition gradient in southern China, his prediction of varying leaf litter N/P ratios is amenable to testing there. Josep Canadell (Global Carbon Project, CSIRO, Australia) concluded the session by focusing our attention on tropical peatlands; large carbon pools that are highly vulnerable to drying and fire. Their sensitivity results in part from disturbance associated with drainage for oil palm cultivation. He described a new laser overflight technique that can characterize the vertical dimension of this carbon pool in unprecedented detail (Hooijer *et al.* 2009; Boehm and Frank, 2008).

Human interactions and mitigations

The fate of the globally significant pool of carbon stored in the biomass and soils of tropical forests largely depends on their future management. Much of the world's tropical forest lands are threatened by pressures from developing economies and

growing populations. Certainly, human intervention will become increasingly important to manage C cycling in tropical countries. Projects to offset industrial C emissions, preserve existing C stores, and sequester additional C from the atmosphere will be critical in tropical regions to mitigate increasing atmospheric CO₂. However, the successful implementation of such projects is challenged by inadequate information about C pools and fluxes at regional and local levels, international cooperation and funding agreements, and the difficulty of C valuation in emerging international markets. Considerable effort is underway to understand and overcome these limitations to tropical C management. Several presentations on day two of the 23rd symposium highlighted research at the forefront of the human-forest interface in the tropics.

María del Carmen Ruiz-Jaen (McGill University, Canada) demonstrated that tropical plantations with high tree species diversity can exhibit higher rates of carbon sequestration and lower rates of soil respiration; a matter of some interest for the use of forest plantations for carbon sequestration (Potvin and Gotelli, 2008; Healy *et al.* 2008). By applying the results from plantation studies, her group has determined that functional trait diversity can be used to predict spatial variation in carbon storage in a nearby natural forest. Knowledge about the relationships among functional diversity, forest structure and carbon storage will provide insight into the design and management of sustainable plantation systems which optimize species diversity, functional diversity, and C sequestration and storage.

The most significant initiative to create international climate policy aimed directly at reducing carbon emissions from land use change is the adaptation of Reduced Emissions from Deforestation and Degradation (REDD) into the United Nations Framework Convention on Climate Change. The REDD initiative would provide international financial and economic incentives to countries which protect forests from carbon loss. Such a program involves the accurate assessment of existing carbon stores, and monitoring those stores over time. The prospect of international carbon accounting poses several scientific challenges for multi-national, accurate, and transparent C assessment and monitoring which are necessary to make REDD feasible. Sandra Brown gave a comprehensive overview of how REDD can become a reality, despite objections posed from several quarters (Gibbs *et al.* 2007). New methods in remote sensing and rapid field assessment of C stocks are currently available; however developed nations must assist in the technology transfer and training necessary to employ those methods on a large scale in developing countries. One new tool in the forest assessment toolbox may be canopy laser profiling, analogous to that mentioned by Canadell earlier (Asner *et al.* 2008; 2009).

Physiological studies

Day two of the symposium continued with presentations addressing the physiological aspects of plant and forest responses and feedbacks to atmospheric CO₂ concentration. Sonja Keel (Princeton University, USA) suggested that tropical forests may continue

to experience growth stimulation from CO₂ increase because they can respond to this carbon supply by rapidly increasing nitrogen fixation. Temperate- and boreal forests may generally lack this capacity, so their response may be limited by available nitrogen pools or atmospheric N deposition (Hedin *et al.* 2009). Andrew Leakey (University of Illinois, USA) cautioned that plant functional types with differing photosynthetic pathways may not all respond equally to CO₂ fertilization, with a particular emphasis on moisture limitations (Ainsworth and Long, 2005). This research has important implications for modeling ecosystem carbon fluxes, and the way altered tropical vegetation types can respond to CO₂ fertilization.

Molly Cavaleri (Michigan Technological University, USA) parameterized a carbon-processing model with field measurements of tissue-level CO₂ exchanges collected via tower access of vertical forest strata, and validated this with eddy covariance (tower) measurements of carbon exchange. She reported that our understanding of temperature and water availability on NEE may still be inadequate within such models. Furthermore, wood growth may not be as tightly coupled to gross primary productivity (GPP) as previously thought. Ping Zhao (South China Botanical Garden, China) described a new technique to combine sapflow-based evapotranspiration with carbon isotope discrimination during photosynthesis to measure instantaneous carbon uptake. The new method provides a novel approach for measuring stand level forest C uptake. Lucy Hutyra (Boston University, USA) used eddy covariance to demonstrate that net ecosystem carbon exchanges (NEE) in old-growth tropical forests can be very sensitive to the timing and intensity of wet/dry seasonal transitions. This research revisited earlier themes regarding the importance of moisture in driving C cycling in tropical forests. In the forest studied, C uptake by the forest canopy was mainly driven by phenology and light, whereas ecosystem respiration was limited by heterotrophic respiration decline in the dry season. Jiangming Mo (South China Botanical Garden, China) described results from a long-term nitrogen amendments experiment that increased nitrous oxide emissions, understory species diversity, dissolved organic carbon loss and reduced total forest species diversity and soil respiration at high levels (Fang *et al.* 2007, 2009a,b; Mo *et al.* 2006, 2008). His group's research indicates the potential for strong interactions between N and C cycling in forests occurring within areas of high atmospheric N deposition.

Poster session

A considerable number of research posters were on display in the main conference room over the course of the symposium. Presenters were given the unique opportunity to briefly explain their research poster to the whole group following the day two oral sessions. Exciting projects from around the world were described, indicating the advancements in C cycling research we can expect in the future. Current research in China was well represented in numerous posters, and the session provided an excellent forum for many Chinese graduate students and young researchers to present their work to international colleagues.

Plant–soil interactions

The final morning of oral presentations focused on plant–soil interactions. Whendee Silver (University of California, Berkeley, USA) started the session by reporting that litterfall and soil respiration are affected by even small changes in temperature and irradiance, implying that these carbon exchange processes are quite sensitive to changes in forest disturbance patterns. Stephan Hättenschwiler (CEFE-CNRS, France) reported that although lignin, nitrogen and phosphorus levels are often linked to leaf litter decomposition rates, those factors are not good predictors in the Amazon. Instead, the carbon ‘quality’ (accessibility for microbial and animal decomposers) is a better predictor (Hättenschwiler and Gasser 2005; Hättenschwiler *et al.* 2008). This work challenges the common “litter quality” paradigm, which may be different for tropical forests than other biomes. Daniel Metcalfe (on behalf of Patrick Meir, University of Edinburgh, UK) used results of a long-term throughfall exclusion experiment to demonstrate that photosynthesis and the respiration of various components are affected in complex ways by simulated drought. (Adams *et al.* 2009; Malhi *et al.* in press). The large scale throughfall reduction experiment is rapidly increasing our understanding of how tropical rainforests respond to drought, and providing necessary data to improve the predictability of land surface models. In the final oral presentation, Sandra Bucci (CONICET, Argentina) drew our attention to hydraulic lift by the roots of tropical savannah vegetation. Characterized both by fire adaptations and long seasonal drought, this major vegetation type has been little studied.

Following the close of the formal presentations the conference delegates took a guided tour of the South China Botanical Garden followed by the conference dinner and cruise of the Pearl River. On the final day a field-trip to the long-term ecological research project at [Dinghushan Biosphere Reserve](#) took place. Several significant findings have been published from research conducted at the reserve, for example rapid carbon accumulation in old-growth forest soils (Zhou *et al.* 2006); experimental nitrogen amendments reduce leaf litter decomposition (Mo *et al.* 2006); these also amendments reduce soil methane uptake (Zhang *et al.* 2008) and soil respiration (Mo *et al.* 2008), and loss of dissolved N during monsoonal rains exceeds that seen in temperate forest studies (Fang *et al.* 2009a,b). Ongoing large-scale monitoring and manipulation experiments at Dinghushan include throughfall (water) reduction, soil water output measurements, nitrogen fertilization, nitrogen and phosphorous fertilizations, nitrogen and carbon dioxide fertilizations, acid deposition increases, decomposition measurements of coarse woody debris, and effects of plant substrate manipulations on soil respiration. These experiments are replicated within three different forest types.

Future

Throughout the meeting the need for tropical FACE experiments in several vegetation types (including plantations, multi-species, secondary and undisturbed forests) was

discussed. It was stressed that tropical carbon-cycle research should be innovative instead of revisiting traditional techniques. Also, large-scale manipulations (temperature, moisture, nutrients, acidity, CO₂) are required, in addition to broad-scale comparisons (e.g., meta-analyses). Many significant publications in Chinese-language journals remain inaccessible to international researchers, and meta-analyses represent one way to bridge this gap. Tropical ecosystem carbon pools remain poorly characterized, yet there are substantial efforts already underway (in the Smithsonian Institution's Center for Tropical Forest Studies permanent plot network for example) to address this. More Asian/international collaborations are needed at the cutting edge of tropical carbon research, and some of those will certainly develop from this symposium.

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