

Biogeochemical Inputs to a Coastal Forested Bornean Peatland

Alexandra G. Ponette-González^{1*}, Lisa M. Curran^{2,3,4,5}, Kimberly M. Carlson⁶, Alice M. Pittman⁴, Bethel Steele, Dwi Astiani⁷, Dessy Ratnasari⁸, Mugiman⁹, Kathleen C. Weathers⁹

¹Department of Geography, University of North Texas, Denton, TX, USA; ²School of Forestry and Environmental Studies, Yale University, New Haven, CT, USA; ³Woods Institute for the Environment, Stanford University, Stanford, CA, USA; ⁴Department of Anthropology, Stanford University, Stanford, CA, USA; ⁵Santa Fe Institute, Santa Fe, NM, USA; ⁶Institute on the Environment, University of Minnesota, Saint Paul, MN, USA; ⁷Department of Forestry, Tanjungpura University, Pontianak, West Kalimantan, Indonesia; ⁸Living Landscapes Indonesia, Pontianak, West Kalimantan, Indonesia; ⁹Cary Institute of Ecosystem Studies, Millbrook, NY, USA. *Corresponding author: alexandra.ponette@unt.edu

Background

- Tropical forested peatlands are ombrogenous, or rainfed, ecosystems, whose only source of nutrients is the atmosphere (rainfall, fog, particles and gases).
- In Borneo, local drainage and burning of forested peatlands for conversion to small- and large-scale agriculture results in atmospheric emissions of nutrient and pollutants, including sulfur (S), nitrogen (N), and phosphorus (P).
- Increasing land conversion may fundamentally alter atmospheric deposition inputs to forested peatlands.

Questions

- What is the rate of wet (rain) S, N, and P deposition (kg/ha/yr) to a coastal forested Bornean peatland?
- What is the magnitude of throughfall S, N, and P deposition from the canopy to the forest floor?
- What is the influence of local fire events on local deposition of S, N, and P to the forest floor?

Methods

- Bulk deposition (rainwater collected in the open) and throughfall deposition (water collected below canopy) of S, N, and P were measured in a 12 ha forested peatland in West Kalimantan, Indonesia.
- Sulfate-S in throughfall was used as a tracer of total (wet + dry + fog) atmospheric deposition, and net S (throughfall – bulk) as an indicator of dry/fog deposition.
- The MODIS Active Fire Product (MCD14ML) was used to determine the number of fire locations within 20 km of the site.

Forested Peatland Plot and Matrix

Fig. 1. Top right. Study site in West Kalimantan, Indonesia (red dot). **Bottom left.** DigitalGlobe image (June 2014) showing the 12 ha forested peatland plot (bounded in white); surrounding matrix of burned peatlands, oil palm plantations, and small-scale agriculture; and location of throughfall (yellow dots) and rainfall collectors (black dots).



Wet S Deposition in an East Asian Context

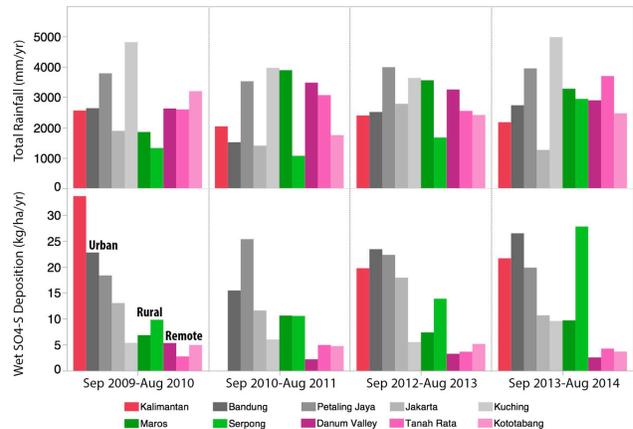


Fig. 2. Compared to Indonesian and Malaysian sites in the East Asia Acid Deposition Monitoring Network (Fig. 1, top right), rainfall input to this forested peatland (2038-2562 mm/yr) was in the middle of the range. Yet, wet SO₄-S deposition was more comparable to urban (grey) than rural (green) or remote (pink) sites, indicating higher SO₄-S concentrations at the study site in West Kalimantan, Indonesia. *Insufficient S data for Sep 2010-Aug 2011.

Deposition of S, N, and P to the Forest Floor

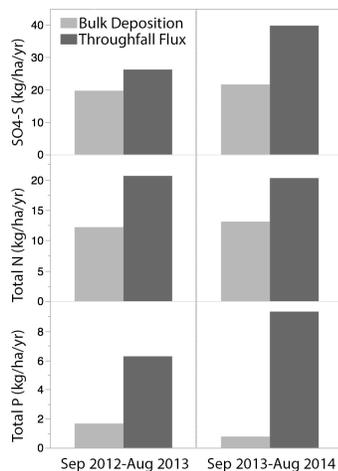


Fig. 3. Sulfate-S, total N, and total P deposition in rain and from the canopy to the forest floor of a coastal Bornean peatland. Throughfall deposition of S and N were nearly 2-fold higher than bulk deposition (rainwater collected in the open), while phosphorus deposition to the forest floor was enriched by as much as 4- and 13-fold compared to bulk deposition. These results highlight considerable inputs from dry/fog deposition and/or canopy leaching.

Fires Enhance Dry Deposition to the Forest Floor

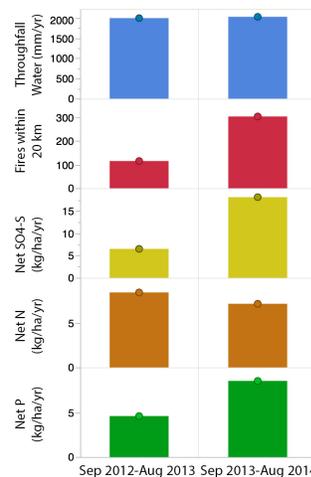


Fig. 4. Net throughfall S deposition was 3-fold higher while net throughfall P deposition was 2-fold higher during 2013-2014 compared to the previous water year, indicating enhanced dry/fog deposition to the forest floor. Throughfall water inputs did not differ between water years, but fire frequency did. There were 303 fires in 2013-2014 compared to 115 fires in 2012-2013. These results suggest that burning around the sample plot contributed to elevated dry S and P deposition.

Acknowledgements

We thank the Indonesian Ministry of Research and Technology (RISTEK) and Indonesian Institute of Sciences (LIPI) for research sponsorship. AGP and LMC were supported by Yale University's Tropical Resources Institute, Council on Southeast Asia Studies, and School of Forestry and Environmental Studies. LMC received financial support from the NASA Land Cover/Land-Use Change Program (NNX11AF08G), Santa Fe Institute, John D. and Catherine T. MacArthur Foundation, Marie Tharp Fellowship, Earth Institute at Columbia University, East-West Center in Hawaii, and Stanford University's Woods Institute for the Environment, Environmental Venture Projects, and Anthropology Department.



Conclusions

- Rates of wet S deposition were exceptionally high (~20-34 kg/ha/yr) and at the upper end of the range relative to urban, rural, and remote sites in Indonesia and Malaysia.
- Fluxes of S, N, and P to this coastal Bornean peatland were 2- to 13-fold higher than inputs in bulk deposition.
- A 3-fold increase in fire frequency in 2013-2014 from 2012-2013 was associated with a 3-fold increase in net throughfall S deposition (an indicator of dry/fog deposition) and a 2-fold increase in net throughfall P deposition. These results suggest that fires have a significant impact on deposition inputs to forested Bornean peatlands.