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Phosphorus limit to the CO_2 fertilization effect in tropical rainforests as informed from a coupled biogeochemical model

Zhuonan Wang[1], Hanqin Tian[1], Shufen Pan[1], Hao Shi[1], Jia Yang[3], Latif Kalin[2], Christopher Anderson[2], and Naishen Liang[4]

[1]International Center for Climate and Global Change Research and School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL, 36849, USA

[2]School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL, 36849, USA

[3]Mississippi State University, Department of Forestry, Mississippi State, MS 39762, USA

[4]Head of Global Carbon Cycle Research Section Center for Global Environmental Research (CGER) National Institute for Environmental Studies (NIES) Tsukuba, Ibaraki, Japan

Tropical rainforests play an important role in sequestering carbon (C) and mitigating climate warming. Many terrestrial biosphere models (TBMs) estimate productivity increase in tropical rainforests due to the CO_2 fertilization effect. However, most TBMs neglect phosphorus (P) limitation on tropical rainforest productivity. Here, we used a process-based Dynamic Land Ecosystem Model with coupled C-N-P dynamics (DLEM-CNP) with varied V_{cmax25} to examine how P limitation has affected C fluxes of tropical rainforests to environmental and anthropogenic factors, including N deposition, land-use changes, climate variability, and atmospheric CO_2, during 1860-2018. The model results showed that consideration of the P cycle reduced the response of tropical rainforests gross primary production (GPP) by 25% and 39%, net primary production (NPP) by 25% and 43%, and net ecosystem production (NEP) by 21% and 41% to the CO_2 fertilization effect relative to CN-only and C-only models. The DLEM-CNP estimated that the tropical rainforests had a GPP of 41.1 + 0.5 Pg C $year^{-1}$, NPP of 19.7 + 0.3 Pg C $year^{-1}$ and NEP of 0.44 + 0.34 Pg C $year^{-1}$ under 1860-2018 environmental conditions. Factorial experiments with DLEM-CNP suggested that deforestation has stronger impacts on GPP and NPP reduction compared to the enhanced GPP and NPP benefiting from the CO_2 fertilization effect. Additionally, tropical rainforests NEP showed a continuously increasing trend owing to the CO_2 fertilization effect. Our study highlights the importance of P limitation on the C cycle and the weakened CO_2 fertilization effect due to nutrients limitation in the tropical rainforests.