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Multiple constraint modeling of nutrient cycling stoichiometry following forest clearing and pasture abandonment in the Eastern Amazon

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While deforestation has declined since its peak, land-use change continues to modify Amazonian landscapes. The responses and feedbacks of biogeochemical cycles to these changes play an important role in determining possible future trajectories of ecosystem function and for land stewardship through effects on rates of secondary forest regrowth, soil emissions of greenhouse gases, inputs of nutrients to groundwater and streamwater, and nutrient management in agroecosystems. Here we present a new synthetic analyses of data from the NASA-supported LBA-ECO project and others datasets on nutrient cycling in cattle pastures, secondary forests, and mature forests at Paragominas, Pará, Brazil. We have developed a stoichiometric model relating C-N-P interactions during original forest clearing, extensive and intensive pasture management, and secondary forest regrowth, constrained by multiple observations of ecosystem stocks and fluxes in each land use. While P is conservatively cycled in all land uses, we demonstrate that pyrolyzation of N during pasture formation and during additional burns for pasture management depletes available-N pools, consistent with observations of lower rates of N leaching and trace gas emission and consistent with secondary forest growth responses to experimental N amendments. The soils store large stocks of N and P, and our parameterization of available forms of these nutrients for steady-state dynamics in the mature forest yield reasonable estimates of net N and P mineralization available for grasses and secondary forest species at rates consistent with observed biomass accumulation and productivity in these modified ecosystems. Because grasses and forests have much different demands for N relative to P, the land use has important biogeochemical impacts. The model demonstrates the need for periodic P inputs for sustainable pasture management and for a period of significant biological N fixation for early-to-mid-successional secondary forest regrowth. The model framework illustrates the relative magnitudes of changing stocks and flows of nutrients and attendant ecosystem functions through the phases of land use change experienced in eastern Amazonia.