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Assessing Impacts of Selective Logging on Water, Energy, and Carbon Budgets and Ecosystem Dynamics in Amazon Forests Using the Functionally Assembled Terrestrial Ecosystem Simulator

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Tropical forest degradation from logging, fire, and fragmentation not only alters carbon stocks and carbon fluxes, but also impacts physical land-surface properties such as albedo and roughness length. Such impacts are poorly quantified to date due to difficulties in accessing and maintaining observational infrastructures, and the lack of proper modeling tools for capturing the interactions among biophysical properties, ecosystem demography, and biogeochemical cycling in tropical forests. As a first step to address these limitations, we implemented a selective logging module into the Functional Assembled Terrestrial Ecosystem Simulator (FATES) and parameterized the model to reproduce the selective logging experiment at the Tapajos National Forest in Brazil. The model was spun up until it reached the steady state, and simulations representative of intact forest and various logging practices and intensity were benchmarked against available eddy covariance and field ecological measurements. Our results suggest that the model realistically characterizes most water and carbon fluxes and stocks, the forest structure and composition, and the ecosystem succession following disturbance. However, the current version of FATES overestimates water stress in the dry season therefore fails to capture seasonal variation in latent and sensible heat fluxes. We also observed a bias towards low stem density and leaf area when compared to observations, suggesting that improvements are needed to allow establishment of additional trees. The effects of logging were assessed by different logging scenarios to represent reduced impact and conventional logging practices, both with high and low logging intensities. The model simulations suggest that even though the degraded forests rapidly recover water and energy fluxes in one to three years compared with old-growth forests, the recovery times for carbon stocks, forest structure and composition are much longer (i.e., more than 30 years depending on logging practices and intensity). Our study highlights the advantages of an Earth system modeling approach, constrained by observations, to quantify the complex interactions among forest degradation, ecosystem recovery, climate, and environmental factors. This study lays the foundation to simulate land use change and forest degradation in FATES, leading the way to direct representation of forest management practices and regeneration in Earth System Models.