EGU22-2537
https://doi.org/10.5194/egusphere-egu22-2537
EGU General Assembly 2022

Logged tropical forests are a net carbon source to the atmosphere as investigated by eddy covariance and biometric ground-based estimates

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Logged and degraded tropical forests are fast becoming one of the most dominant land-use types throughout the tropics, yet there is limited understanding of the impact of logging on tropical forest function and carbon balance. To date, previous research on the carbon dynamics of logged and degraded forests has mostly focused on carbon stock recovery during forest regrowth and asserted these ecosystems as an important carbon sink due to rapid increase in stem biomass. These estimates of biomass sink function do not, however, serve as an assessment of the ecosystem carbon balance, as they do not include estimates of the carbon losses through ecosystem respiration, particularly from heterotrophic sources. We quantified the complete carbon budget in old-growth, moderately logged, and heavily logged forests within Malaysian Borneo, a region that is a hotspot for deforestation and degradation. We present the first direct measurements of net ecosystem CO_2 exchange from a logged and structurally degraded tropical forest and show how this landscape represents a substantial net carbon source to the atmosphere, using both eddy covariance technique and ground-based biometric estimates. We estimated a net carbon source of 4.66 ± 1.36 Mg C ha^{-1} year^{-1} across the logged plots sampled (n=5), compared to 0.69 ± 1.06 Mg C ha^{-1} year^{-1} within old-growth plots (n=6). Our results showed a high level of variability along the logging gradient, ranging from 1.88 ± 4.29 Mg C ha^{-1} year^{-1} in a moderately logged plot to 8.16 ± 4.16 Mg C ha^{-1} year^{-1} in a heavily logged plot, highlighting that unsustainably logged areas function as substantial net carbon sources. Eddy covariance measurements over the heavily logged landscape estimated a net carbon source of 12.24 ± 2.06

$Mg\ C\ ha^{-1}\ year^{-1}$, similar to that of the heavily logged biometric plot located within its footprint. Consistent with existing literature, our study showed a significantly greater woody biomass gain during regrowth across moderately and heavily logged forests, compared with old-growth forests. This was not due to higher total net primary productivity but due to an allocation shift towards the increased production of woody tissue. Gross and net primary production was largely unaffected by logging, but ecosystem respiration, particularly from heterotrophic sources was significantly higher in logged forests. Despite increased tree growth rates within recovering logged forest compared to old-growth forests, these systems do not necessarily function as a net carbon sink, especially if past disturbances cause persistent carbon losses from soil and necromass. We, therefore, demonstrate critically how focussing on carbon gain from woody biomass accumulation alone does not provide a complete picture of carbon cycling within logged tropical forests, and how heavily degraded forests function as net carbon sources.