Supporting Information

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SI Text

Logging Damage Surveys. A postlogging survey in December 2001 of an 18-ha plot (600 m E-W × 300 m N-S) east of the eddy covariance tower found that 70 trees had been logged with an average diameter at breast height (DBH) of 82 cm. Bole wood from 65 of the trees had been removed from the site, and entire boles from the other 5 trees remained on the forest floor. The average length of bole moved off site was 20 m $tree^{-1}$, estimated as the distance between the stump and the remaining crown, corresponding to 5.9 ± 0.9 MgC ha^{-1} (Table S1). The remaining bole wood (3.2 ± 0.5 MgC ha^{-1}) remained on the forest floor as coarse woody debris (CWD). The postlogging damage survey data are available online (1).

The average canopy loss of 304 trees damaged by logging was 57%. An additional 447 trees had their bole snapped at an average height of 6.8 m. The biomass deposited to the forest floor from killed and damaged trees amounted to 5.8 ± 1.0 MgC ha^{-1}, and another 0.9 ± 0.2 MgC ha^{-1} of dead biomass remained standing. Total CWD was 14.9 ± 2.4 MgC ha^{-1}. Logging-induced leaf and fine litter debris were estimated based on litter production rates measured at the logged site (2) and control site (3), assuming a 1-y turnover time. The leaf and fine litter data are available online (4, 5).

Flux Footprints. The logging extended roughly 3 km in the upwind (east) direction of the flux tower. Estimates of the flux footprint were calculated using an analytical model (6). During daytime, 80% of the flux was accumulated within 1 km of the tower, and >90% of the flux within 3 km. During nighttime, 60% of the flux was accumulated within the 3 km extent of the logging. We compared measured nighttime net ecosystem exchange (NEE) when $u_* > 0.22$ m s^{-1} with an independent estimate of ecosystem respiration obtained from a light response model applied only to daytime measurements, when the flux footprint was within the extent of the logging. A comparison of these two independent estimates of respiration (R) showed good agreement (7).

Use of Unlogged Site as Experimental Control. At the start of the experiment, measurements at both the unlogged and logged Tapajos National Forest (TNF) sites showed higher-than-expected proportions of small trees (3, 8) and large amounts of CWD on the forest floor (3, 9, 10). At the unlogged site, CWD decreased over a several-year period (3). These observations were consistent with a pre-experiment disturbance at the TNF. This possibility was reinforced by observations of increased allocation of gross primary production (GPP) to wood growth, and less to respiration, at the unlogged TNF site compared with forests in the central and eastern Amazon (11). The nature and timing of a pre-experiment disturbance has been hypothesized, yet remains unknown (12, 13). Alternatively, it has been suggested that the large CWD pools could be consistent with higher turnover rates in the TNF relative to other Amazonian forests (14).

To examine the sensitivity of our results to a possible prelogging disturbance at TNF, we calculated the intersite NEE difference, ΔNEE, using different scenarios that represent end members for the possible impact of a prelogging disturbance. The first assumption was that either there was no prelogging disturbance at either site, or that any disturbance affected the sites equally. In this scenario, the measured NEE at km 67 (Fig. S2*A*, dark shaded boxes) was used to calculate the intersite difference, ΔNEE (Fig. S2*B*, dark shaded boxes). This case was used in Fig. 3*C*.

The second scenario is that km 67 was disturbed before logging, but km 83 was not. For this scenario, an ecosystem carbon box model was developed to simulate the transient transfer of carbon among live and dead pools as the forest moved toward a steady state, using comprehensive measurements of carbon pools and fluxes from the unlogged site as model inputs (Fig. S2*A*, dashed curve) (12). The model indicated a net loss of carbon from the unlogged site that decreased slowly throughout the study interval. Adjusting the measured control site NEE to account for the modeled disturbance recovery showed a net carbon balance closer to zero (Fig. S2*A*, light boxes). However, the adjustment had a minor effect on ΔNEE when the postlogging changes were calculated relative to the prelogging ΔNEE (Fig. S2*B*). Without the adjustment, ΔNEE for the first 3 y after logging was 1.4 MgC $ha^{-1}y^{-1}$ relative to the prelogging period, compared with 0.9 MgC $ha^{-1}y^{-1}$ with the adjustment (Table S2). The difference between ΔNEE with and without adjustment was within the measurement uncertainty; therefore, the possible effects of prelogging disturbance did not affect our conclusion that reduced impact logging had only minor carbon-cycle impacts.

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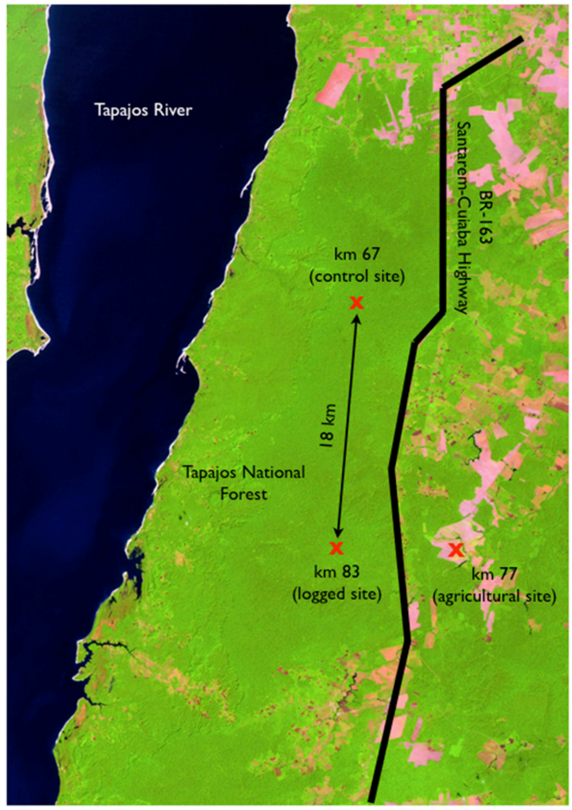

Fig. S1. LandSat image of Tapajos National Forest, Para, Brazil. The flux tower locations shown as black X: control site (km 67), logged site (km 83), and the agricultural site (km 77). The N-S road is the Santarem-Cuiaba highway (BR163).

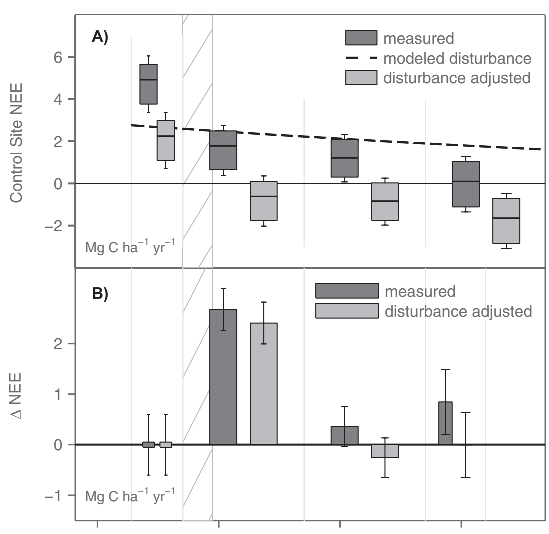

Fig. S2. (*A*) Averaged NEE ($MgC{\cdot}ha^{-1}{\cdot}y^{-1}$) at the control site (km 67) in the Tapajos National Forest, Para, Brazil: measured NEE (dark box plots), modeled NEE because of disturbance (dashed curve) (1), and measured NEE adjusted for disturbance (light box plots). Horizontal line at center of each box plot is mean gap-filled NEE, shaded box plot limits are mean NEE for $u_* = 0.17\ m{\cdot}s^{-1}$ and $u_* = 0.27\ m{\cdot}s^{-1}$ filters. (*B*) Difference between NEE at the logged and unlogged sites. Vertical hatched region September 15 to December 15, 2001 indicates logging period. Error bars on boxes are the uncertainty because of gap filling and sampling.

Table S1. Effect of logging on above ground biomass pools in an 18-ha plot east of eddy flux tower at Tapajos National Forest, Para, Brazil

Biomass	Per tree (MgC)	Sum of trees (MgC)	Density (MgC ha^{-1})
Logged tree biomass	3.2–4.4	224–306	12.5–17
Bole removed from site	1.3–1.7	89–122	5.0–6.8
Bole remaining (CWD)	0.7–0.9	48–65	2.7–3.6
Crown down (CWD)	1.3–1.8	90–123	5–6.9
Damaged/killed tree biomass	—	252–352	14–20
Damaged/killed CWD (forest floor)	—	86–120	4.8–6.7
Damaged/killed CWD (standing)	—	13–19	0.7–1.0
Total CWD added to forest floor	—	224–308	12.5–17.2

Biomass calculated as a range with the low end based on allometric equations for trees in Manaus, Brazil, and the high end for a range of tropical moist forests (1). Because biomass of subpools (boles, crowns) was only reported by Chambers et al. (2) using the Manaus allometry, a factor 1.4 was used to calculate subpool biomass for the tropical moist forest allometry.

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Table S2. Average fluxes of carbon (MgC·ha^{-1}·y^{-1}) and sensible and latent heat (W·m^{-2}) at the control (km 67) and logged (km 83) sites in Tapajos National Forest, Para, Brazil

Site	GPP (MgC·ha^{-1}·y^{-1})	R (MgC·ha^{-1}·y^{-1})	NEE (MgC·ha^{-1}·y^{-1})	H_S (W·m^{-2})	H_L (W·m^{-2})
Control Site (km 67)					
Before logging (6 mo)	26.0 ± 1.5	30.9 ± 2.5	4.9 ± 1.5 (2.2 ± 1.5)	21.5 ± 0.8	79.3 ± 1.6
Years 1–3 after	31.1 ± 1.4	32.1 ± 2.3	1.0 ± 1.2 (−1.0 ± 1.2)	20.4 ± 0.3	85.3 ± 0.6
Logged Site (km 83)					
Before logging (12 mo)	32.6 ± 1.3	31.9 ± 1.7	−0.6 ± 0.8	22.5 ± 0.6	100.4 ± 1.2
Before logging (6 mo)	29.6 ± 1.8	31.2 ± 1.9	1.7 ± 0.9	25.1 ± 0.9	99.0 ± 1.7
Years 1–3 after	32.0 ± 1.1	31.0 ± 1.6	−1.0 ± 0.7	25.8 ± 0.4	101.3 ± 0.8
Logged site-control site					
Before logging (6 mo)	3.6 ± 0.9	0.4 ± 0.6	−3.3 ± 0.6 (−0.6 ± 0.6)	3.6 ± 1.1	19.7 ± 2.4
Years 1–3 after	0.9 ± 0.3	−1.1 ± 0.2	−2.0 ± 0.3 (0.3 ± 0.3)	5.4 ± 0.4	15.7 ± 1.0

All fluxes include sampling and gap-filling uncertainty. Carbon fluxes (GPP, R, NEE) for each site also include additive uncertainty because of u_*-filter cutoff (see *Materials and Methods*). Uncertainty in intersite carbon flux differences (ΔGPP, ΔR, ΔNEE) was calculated as the square root of the sum of squared sampling and gap filling uncertainties at each site; the u_*-filter uncertainty was not included as both sites were found to require the same filter cutoff (12). Values in parenthesis were calculated assuming a pre-experiment disturbance at the control site that did not occur at the logged site, as described in *Use of Unlogged Site as Experimental Control* in *SI Text*.

Table S3. Carbon budget from ecological and meteorological measurements at the logged site at Tapajos National Forest, Brazil

	Before logging	After logging	Change	Uncertainty in change
GPP	32.6	29.9	−2.7	2.5
R	32	30.5	−1.5	1.5
R_a = GPP − NPP	23.1	20.1	−3.0	3.5
R_h	8.9	10.4	1.5	2.7
NPP_{wood}	1.7	2.5	0.8	1.0
NPP_{leaf}	5.3	4.8	−0.5	1.6
NPP_{root}	2.5	2.5	0	1.0
NPP	9.5	9.8	0.3	2.2
Mortality	1.7	4.5	2.8	1.6
Litter production	7.8	7.3	−0.5	1.9
Mortality+litter production	9.5	11.8	2.3	2.5
Live biomass change	0	−2.0	−2.0	3.2
Necromass change	0.6	1.4	0.8	3.7
NEP	0.6	−0.6	−1.2	1.3

Carbon budget from ecological and meteorological measurements at the logged site at Tapajos National Forest, Brazil, for the year before and 3 y after reduced impact logging (see Fig. 4). Positive GPP, NEP, NPP, and live biomass for carbon flux to forest; positive R, necromass, and decomposition for carbon flux from forest. Calculation of changes in the fluxes and their uncertainties described in *Materials and Methods*. All quantities in $MgC{\cdot}ha^{-1}{\cdot}y^{-1}$. GPP, gross primary production; NEP, net ecosystem production; NPP, net primary production.

Table S4. Remote sensing (MODIS) albedo at the logged (km 83) and control (km 67) sites in the Tapajos National Forest, Para, Brazil, and for a nearby pasture site (km 77)

Site	Year before	Year 1–3 after
MODIS albedo		
km 67 (control site)	0.142	0.136
km 83 (logged site)	0.145	0.139
km 77 (pasture site)	0.154	0.168
Intersite ratios		
km 83/km67	1.03 ± 0.04	1.04 ± 0.02
km 77/km67	1.24 ± 0.04	1.34 ± 0.03

Ratios of sites include only times when valid data available at both sites. The 95% confidence interval ranged 0.003–0.005, calculated using a bootstrap method.

Table S5. Tree DBH increment rate ($cm{\cdot}y^{-1}$) and wood production ($MgC{\cdot}ha^{-1}{\cdot}y^{-1}$) at the logged and control sites in the Tapajos National Forest, Para, Brazil, measured using dendrometer bands, for the 6-mo period before logging, and 36-mo period after logging

			Growth rate ($cm{\cdot}y^{-1}$)		NPP_{wood} ($MgC{\cdot}ha^{-1}{\cdot}y^{-1}$)	
Site	Tree density stems ha^{-1}	No. of bands	Prelog	Postlog	Prelog	Postlog
Control Site	516	763*			3.1 ± 0.4	4.0 ± 0.5
10–35 cm	465	529	0.2 ± 0.02	0.28 ± 0.03	1.7 ± 0.2	2.3 ± 0.2
35–55 cm	30	119	0.43 ± 0.05	0.52 ± 0.07	0.6 ± 0.1	0.7 ± 0.1
55–100 cm	21	115	0.41 ± 0.08	0.54 ± 0.09	0.7 ± 0.2	1.0 ± 0.2
Logged Site	482	691†			1.7 ± 0.4	3.4 ± 0.4
10–35 cm	422	363	0.14 ± 0.03	0.31 ± 0.03	0.9 ± 0.2	2.0 ± 0.2
35–55 cm	37	223	0.26 ± 0.05	0.47 ± 0.05	0.4 ± 0.1	0.7 ± 0.1
55–100 cm	23	105	0.20 ± 0.08	0.43 ± 0.07	0.4 ± 0.2	0.7 ± 0.1

*Fewer bands than Rice et al. (3). We retained only bands that were in place as of February 2001, when logged site measurements began, and which were surveyed in 2001 and 2005.

†More bands than the 234 reported Figueira et al. (8). We retained additional bands by accounting for step changes in the data when bands were readjusted.