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Supporting Online Material for

Tropical Forests and Climate Policy

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Published 10 May 2007 on *Science* Express
DOI: 10.1126/science.1136163

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SOM Text

Carbon emissions from tropical deforestation

Tropical deforestation released c. 1.4 GtC yr^{-1} (range: 0.9–2.2) (calculated as the average and range of *S1*–*S3*) throughout the 1990's, accounting for 17.3% (range: 12.0–28.0) (*S4*, *S5*) of total annual anthropogenic greenhouse gas emissions during this period.

Cumulative carbon emissions reductions required to stabilize at 450 ppm CO_2

Cumulative carbon emissions from 2010–2100 allowed under the WRE-450 stabilization scenario were calculated as follows. First, the IPCC allowable emissions from 2001 to 2100 for this scenario range from 365 to 735 GtC, based on uncertainty in rates of carbon uptake by the ocean and terrestrial biosphere (*S6*). The mid-range estimate of emissions from 1991 to 2000 under the "S" concentration profiles is 630 GtC (*S7*). Subtracting estimated global emissions of 57.6 GtC (*S8*) for 1990–1999 from 630 GtC gives a mid-range estimate of 572 GtC from 2000 to 2100. The next step is to adjust the range and mid-point from 2000 to 2010. Global emissions from 2000 to 2003 total 27.8 GtC. SRES-projected emissions in 2010 are 8.4 GtC (*S9*). Filling in estimated global annual carbon emissions between 2004 and 2010 by linearly interpolating between 2003 values and SRES-projected 2010 emissions gives total cumulative emissions from 2000 to 2009 of 74.9 GtC. Subtracting this value from the cumulative emissions allowed from 2000 to 2100 gives a mid-point of allowable carbon emissions from 2010 to 2100 of 498 GtC, with a range of 297 to 667 GtC. For comparison, total cumulative carbon dioxide emissions for the A2 and B2 SRES emission scenarios over the period 2010 to 2100 are 1785 and 1090 GtC respectively (Fig. S1).

Note that limiting global average temperature increases to 2°C above pre-industrial levels, the target adopted by the European Union (*S10*), could require more ambitious reductions (Fig. S2) (*S11*).

Emissions reductions from slowing deforestation

Houghton (2005) (*S12*) estimates projected emissions from tropical deforestation as follows. First, deforestation rates and emissions during the 1990s have been estimated based on satellite imagery (*S13*) and based on sampled country inventory data (*S14*, *S15*). For simplicity, Houghton (2005) assumes deforestation rates and associated emissions stay constant for each country until remaining forested area in that country reaches 15% of the forest area in 2000. At that point, deforestation is assumed to halt as the remaining forested area is already protected or is located in a region that is not cost-effective to clear (Fig. S3).

To assess the potential reductions in projected carbon emissions that could be obtained through substantial measures to reduce tropical deforestation, we re-calculated the carbon emissions that would result from (a) a linear reduction in deforestation rates to 20% and 50% below 1990s rates by 2050, and (b) stopping deforestation when 50% of forested area relative to 2000 was still remaining, rather than just 15% as in the Houghton (2005) estimates. Figure S4 compares the baseline emissions, taken as the average of 1990's emissions based on satellite and sampled country inventory data, with the emissions based on slowing deforestation rates and increasing the remaining forest area at which deforestation halts. Slowing rates to 50% below 1990's rates by 2050 results in more than 50% of the forested area still remaining by 2100 for most tropical countries.

How much of a contribution to global carbon emissions reductions could the reductions in deforestation examined here make? In 2003, annual global emissions slightly exceeded 8.9 GtC yr^{-1} (*S5*, *S8*). Deforestation reductions from 2010 to 2100 under these scenarios have the potential to reduce emissions by 13–50 GtC, which is equivalent of up to 5.6 years of global emissions at present-day levels (Fig. 1). The potential contribution of these reductions towards the total emission reductions required to stabilize atmospheric CO_2 levels at 450 ppm through 2100 is up to 12%, depending on total industrial emissions over this period and the uptake of CO_2 by the biosphere (Fig. S4).

Are emissions reductions of the magnitude discussed here feasible? Drawing on several recent global forest sector economic models estimating the cost of achieving emission reductions through reduced deforestation, the IPCC (table 9.3 in *S16*) estimates that the mitigation potential of reduced tropical deforestation is 1.04 GtC/yr in 2030, of which 55% (0.57 GtC/y) could be accomplished at prices up to U.S.$20 per tCO_2. By contrast, the most aggressive emission reduction scenario considered here (reducing deforestation rates by 50%, and stopping deforestation altogether when 50% of original forest area remains) would require annual emission reductions of c. 0.41 GtC/y in 2030. Hence, emission reductions from reduced deforestation equal to or greater than the scale considered here appear feasible at moderate carbon prices.

Using a price of U.S.$20 per tCO_2, the *average annual cost* of emission reductions over the period 2010–2100 would be (in billions of dollars) U.S.$10.5, $26.9, $33.4, or $40.8, for the 13, 33, 41, and 50 GtC scenarios, respectively. Actual costs could be considerably lower, as the IPCC identifies U.S.$20 per tCO_2 as an upper threshold for price.

The impact of deforestation on Amazon rainfall

When global climate models simulate Amazon deforestation, they typically find that precipitation decreases approximately linearly with increasing amounts of deforestation. Maximum precipitation reductions of 5–30 % are seen at complete deforestation (*S17*, *S18*). However, meso-scale models, with finer spatial resolution, fail to find the same pattern (*S19*). Instead of a uniform decrease in precipitation, they show complex patterns of change, with some areas increasing and others decreasing, but not necessarily a marked decrease in overall precipitation.

Supporting Figures

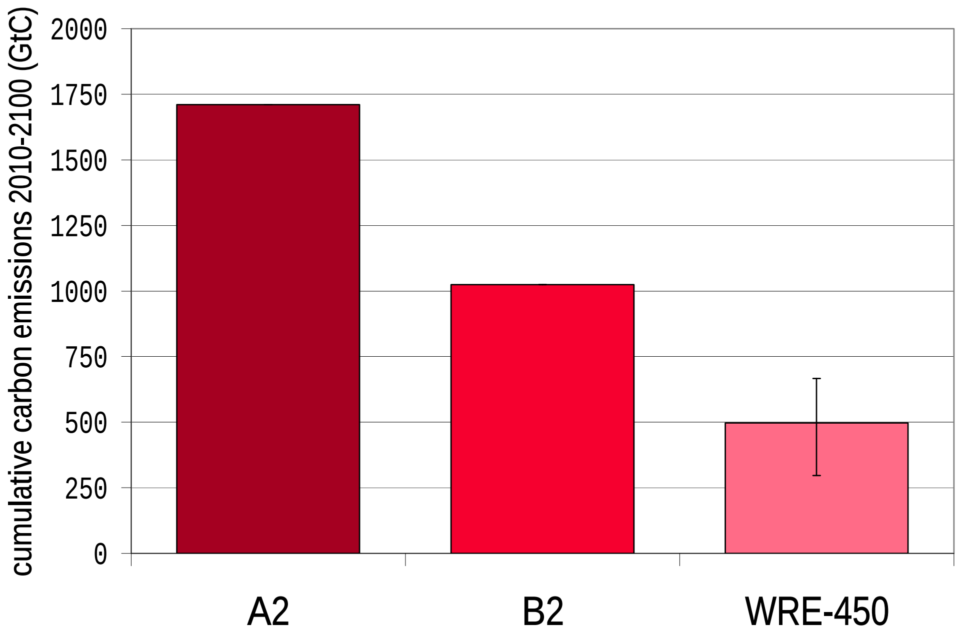


Figure S1. Cumulative carbon emissions for the SRES mid-range A2 and B2 marker scenarios, as compared with emissions under the WRE-450 stabilization pathway. The range in cumulative emissions under the WRE scenario represents uncertainty in carbon uptake by the marine and terrestrial biosphere.

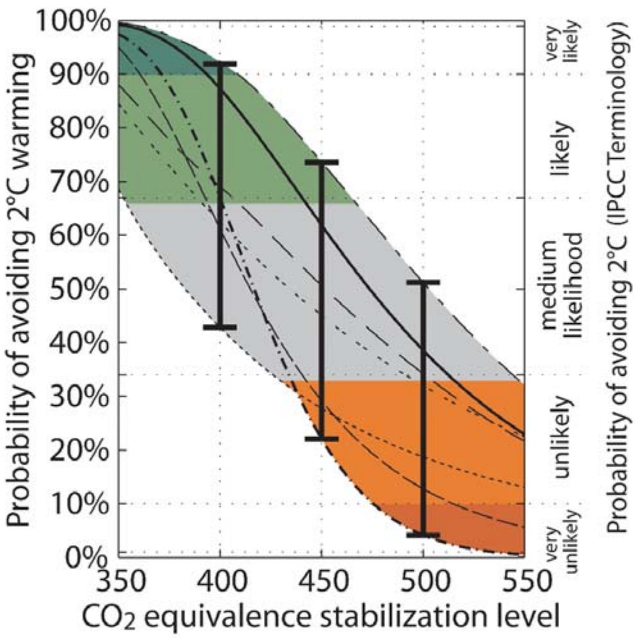


Figure S2. Probability of avoiding (i.e., remaining below) a global 2°C warming target as a function of CO_2-equivalent stabilization levels. Uncertainty range is determined by current estimates of climate sensitivity [redrawn from (*S11*)]. CO_2 concentrations are currently at approximately 385 ppm, while CO_2-equivalent concentrations, which include other gases such as CH_4, N_2O, SF_6 and CFCs, are approximately 425 ppm.

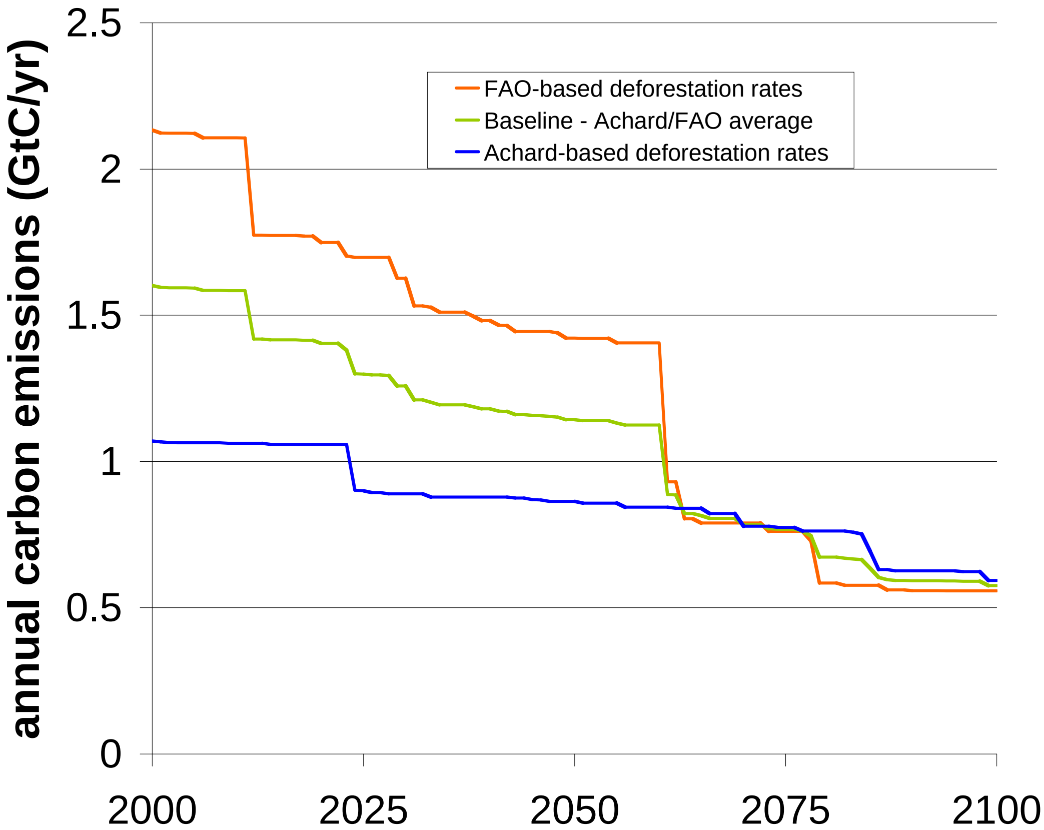


Figure S3. Annual emissions of carbon from tropical deforestation summed over Africa, Asia & Latin America, based on FAO (*S14*) (orange), Achard *et al*., 2004 (*S13*) (blue) and the average of the two estimates (green), which we use as the baseline for this analysis. Emissions assume that rates of deforestation for the 1990s continue in the future, after Houghton (2005) (*S12*). Deforestation is estimated to halt when each country's forest area reaches 15% of its forested area in 2000.

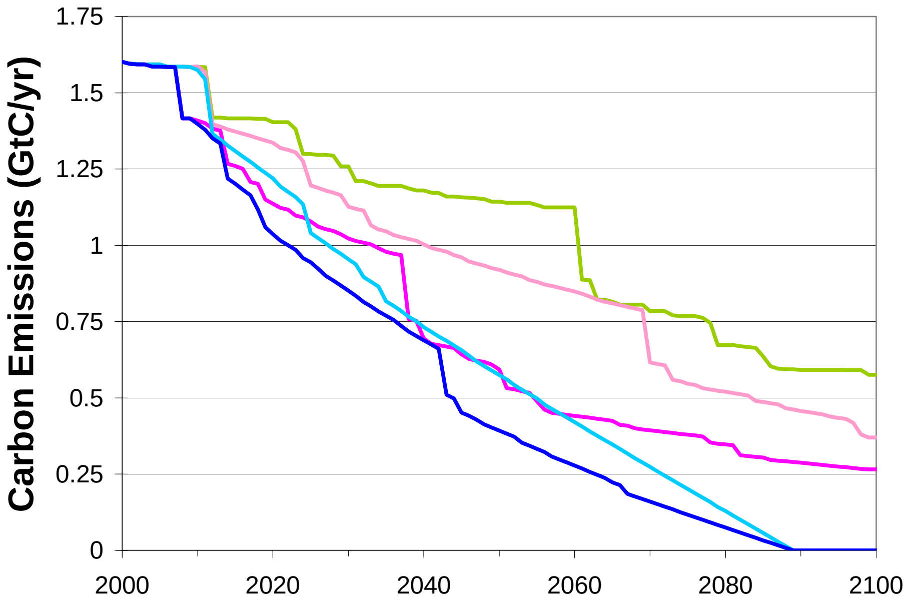
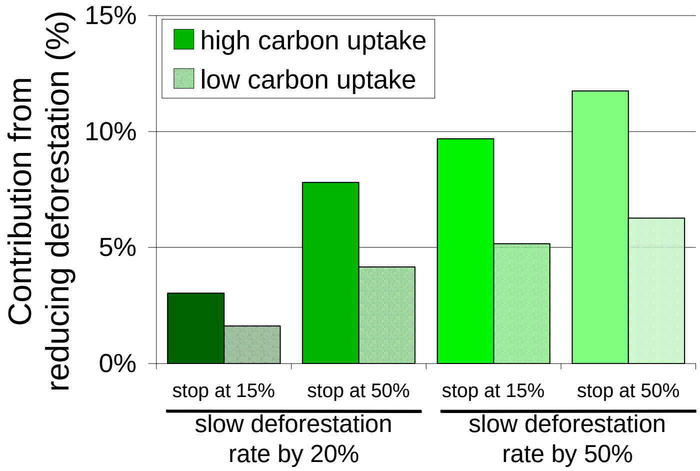


Figure S4. Baseline global emissions from deforestation as estimated by Houghton, 2005 (*S12*) (green). The pink lines show the emissions based on a 20% slowing in deforestation rates by 2050 relative to 1990s average, stopping at 15% of remaining forest area by individual country (light pink) or 50% of remaining area (dark pink). Similarly, the blue lines show emissions corresponding to a 50% slowing in deforestation rates by 2050 stopping at 15% (light blue) or 50% (dark blue) of remaining forest area by individual country.

A



B

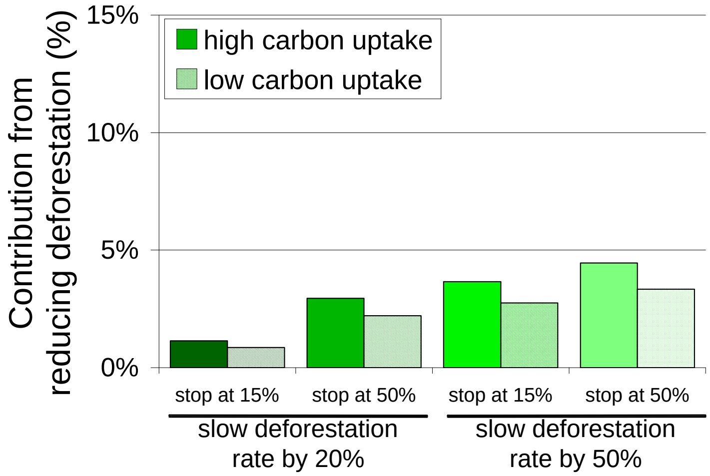


Figure S5. The contribution of reduced tropical deforestation towards achieving a 450 ppm stabilization pathway. The deforestation scenarios are defined by two variables. First, current day deforestation rates are reduced by either 20% or 50% by 2050, and then maintained at these levels until 2100. Second, deforestation stops entirely once forest cover has been depleted to either 15% or 50% of forest area in 2000. The analysis considers both low- and high future carbon uptake scenarios by the marine and terrestrial biosphere (*S6*). (**A**) The contribution of reduced deforestation under the SRES A2 medium-high emissions scenario, which projects cumulative carbon emissions of 1785 GtC from 2010 to 2100. Allowable emissions for the WRE-450 stabilization pathway range from 297 to 667 GtC over the same period, meaning that the cumulative emission reductions required are 1118–1488 GtC. (**B**) The same as (A), but using the SRES B2 mid-range emissions scenario, which predicts cumulative carbon emissions of 1090 GtC between 2010–2100, and would require emission reductions of between 423 and 793 GtC to be consistent with a 450 ppm stabilization pathway.

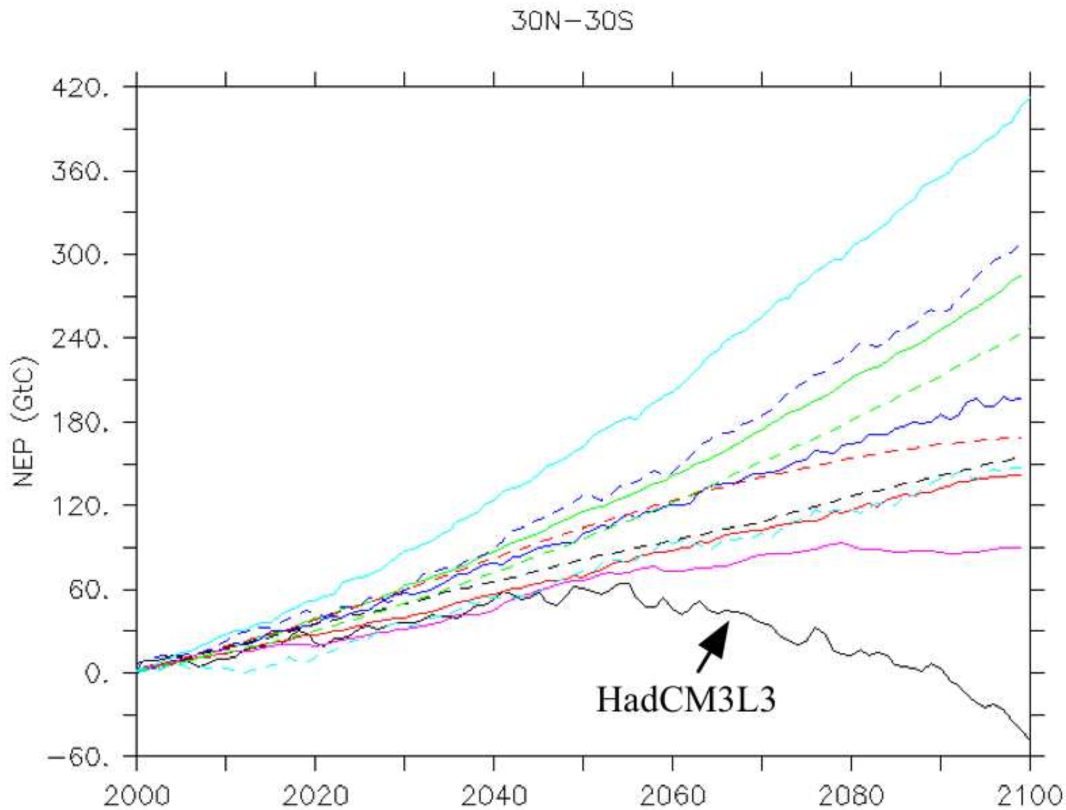


Figure S6. Cumulative change in Net Ecosystem Productivity (NEP) in the tropics from 2000 to 2100 for the eleven models participating in the Coupled Climate-Carbon Cycle Model Intercomparison Project. Models use the medium-high SRES A2 emission scenario, which assumes that atmospheric CO_2 concentration will exceed 550 ppm by mid-century, and reach 850 ppm by 2100. Results show the combined effects of climate change and CO_2 fertilization. Projected land-use emissions are included in the simulations, but land use *per se* is not modeled, and does not influence the distribution of natural vegetation. Most models show that sink strength declines over time, with one model (HadCM3LC) projecting that tropical forests become net sources of carbon. [Key to models: HadCM3LC (solid black), IPSL-CM2C (solid red), IPSL-CM4-LOOP (solid yellow), CSM-1 (solid green), MPI (solid dark blue), LLNL (solid light blue), FRCGC (solid purple), UMD (dash black), UVic-2.7 (dash red) and CLIMBER (dash green), BERN-CC (dash blue). See (*S20*) for full description.] Aggressive efforts to reduce industrial and deforestation emissions would likely further reduce the rate of decline and risk of reversal of the tropical sink. Under a 450 ppm CO_2 stabilization scenario, for example, Amazon dieback-associated emissions for the HadCM3L3 model are reduced 43 GtC, or 45%, through 2100 (S*21*).

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S4. Net tropical deforestation emissions from the average and range of refs. S1–S3 are divided by total anthropogenic emissions (6.4 GtC yr^{-1} from fossil fuels and cement production, and 1.6 GtC yr^{-1} from global land use change). Data from ref. S*5*.

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