CO_2 emissions from forest loss

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Deforestation is the second largest anthropogenic source of carbon dioxide to the atmosphere, after fossil fuel combustion. Following a budget reanalysis, the contribution from deforestation is revised downwards, but tropical peatlands emerge as a notable carbon dioxide source.

Programmes that aim to reduce the emissions from deforestation and forest degradation are being considered as a cost-effective way to mitigate anthropogenic greenhouse-gas emissions[1]. Deforestation and forest degradation contribute to atmospheric greenhouse-gas emissions through combustion of forest biomass and decomposition of remaining plant material and soil carbon. Within the science and policy communities, carbon emissions from deforestation and forest degradation have been estimated to account for about 20% of global anthropogenic CO_2 emissions[2–5]. A recalculation of this fraction using the same methods, but updated estimates on carbon emissions from both deforestation and fossil fuel combustion suggests that in 2008, the relative contribution of CO_2 emissions from deforestation and forest degradation was substantially smaller, around 12%. As a consequence, the maximum carbon savings from reductions in forest decline are likely to be lower than expected.

Deforestation is the long-term reduction of tree canopy cover[6] to below 10–30%. In practice, deforestation is associated with the conversion of forest to other types of land use, such as cropland or pasture. Forest degradation is typically considered partial deforestation, with more than 10–30% of forest cover remaining (for example, through selective logging). Land degradation that does not involve changes in tree cover density, such as oxidation and combustion of deforested and drained tropical peatlands[7,8], may also involve substantial carbon emissions. However, losses of these non-forest carbon stocks are not generally included in deforestation and forest degradation assessments, as summarized in the 2007 report of the Intergovernmental Panel on Climate Change (IPCC) Working Group I (ref. 2), nor are they considered in policies aiming to reduce emissions from deforestation and forest degradation (REDD).

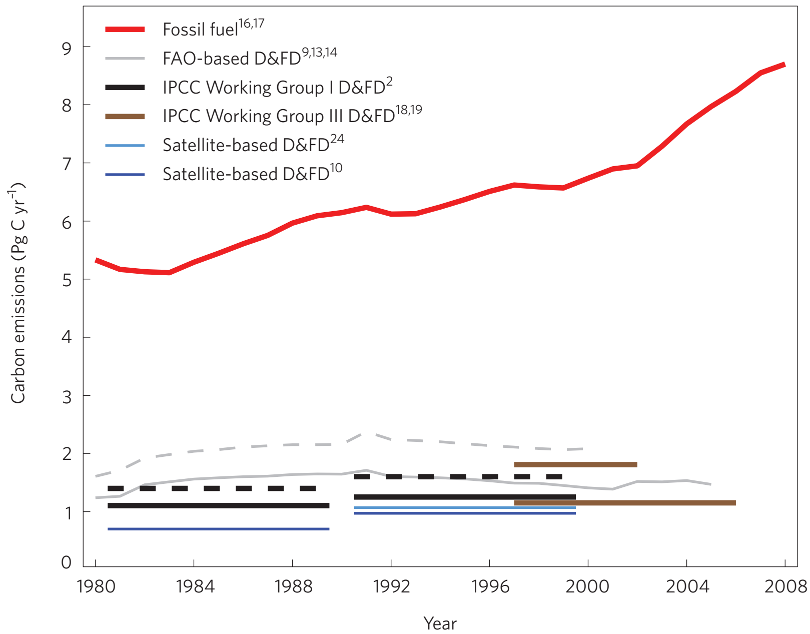

Figure 1 | Carbon emissions from deforestation and forest degradation (D&FD) and fossil fuel emissions for 1980 onwards. Updated datasets and approaches are depicted with a solid line, outdated ones with a dashed line. The often-held assumption that deforestation and forest degradation accounts for 20% of global anthropogenic CO_2 emissions is calculated using the average (dashed black line) of the deforestation surveys from the Food and Agricultural Organization (FAO; dashed grey line) and satellites in the 1990s (dark blue line), compared with average fossil fuel emissions estimates for the 1990s (red). Revised FAO-based emissions estimates (solid grey line) together with increased fossil fuel emissions substantially lower the relative contribution of deforestation and degradation to total anthropogenic emissions to about 12%. Dashed brown line indicates D&FD assessment used in IPCC Working Group III; solid brown line follows the same approach, but is based on updated carbon emissions from tropical forest fires used in this approach. Error bars are not shown, but the uncertainty in the deforestation figures is large, up to 50%. Peatland carbon emissions (0.30 Pg C yr^{-1}) are not included in emissions estimates.

The two main assessments of CO_2 emissions from deforestation and forest degradation for the 1980s and 1990s — one based on surveys by the Food and Agricultural Organisation (FAO)[9] and the other based on satellite data[10] — have limitations[11,12], and one is not obviously preferable to the other. Therefore, IPCC Working Group I averaged emissions estimates from the two approaches for their estimate of carbon emissions from deforestation and forest degradation (Fig. 1). However, since the IPCC assessments were written, the FAO has lowered its estimate of deforestation and forest degradation rates, leading to a 30% reduction in related carbon emissions[13,14] (Fig. 1). Furthermore, an updated satellite-based estimate of deforestation rates[15], derived from changes in tree cover density in the humid tropics during 2000–2005, suggested that rates are similar to those in the previous decade[10], resulting in estimates that are still lower than those reported in the revised FAO survey.

A recalculation, using IPCC methods and these updated values, suggests CO_2 emissions from deforestation and forest degradation (excluding peatland emissions) of about 1.2 Pg C yr^{-1} — 23% less than the value given in the 2007 report of the IPCC Working Group I. In this calculation, we assume that rates of forest decline for 2000–2005 were almost the same as in the 1990s, based on survey[14] and satellite-based approaches[15] of deforestation area (Fig. 1). Carbon emissions from fossil fuel combustion have increased substantially over the same period[16,17], making the relative contribution from deforestation and forest degradation even smaller. As a result, deforestation and forest degradation emissions contribute about 12% of total anthropogenic CO_2 emissions (updated from 20%). Taking into account the large uncertainties in the deforestation and degradation estimates[2], the range becomes 6–17%.

In addition to the emissions assessment of the IPCC Working Group I (*The Physical Science Basis*), an independent assessment[18,19] was carried out by the IPCC Working Group III (*Mitigation of Climate Change*), based on carbon emissions released by fires in tropical forest areas. This approach assumed that half of the total CO_2 emissions from deforestation and forest degradation come from forest fire, whereas the remainder can be attributed to respiration of leftover materials[18,20]. Carbon emissions from tropical peatland burning and oxidation in Southeast Asia[8], mostly in Indonesia, were included in their assessment. Combined with deforestation and forest degradation, this estimate of the contribution of forest and peatland decline amounted to 23% of total CO_2 emissions (or 17% of all anthropogenic greenhouse gases released into the atmosphere; see Supplementary Information).

However, the IPCC Working Group III assessments also need to be revised down in the light of new information: data updates led to a 32% decrease in the estimates of fire-related carbon emissions from deforestation and forest degradation, resulting in a revised deforestation and forest degradation average of 1.2 Pg C yr^{-1} over the period 1997–2006 (refs 17, 21). Furthermore, carbon emissions from Southeast-Asian peatland fires, constrained by satellite-derived column-mixing ratios of carbon monoxide[22], were less than half of those used in the IPCC Working Group III report. Yet even this lower value of the contribution from peat fires highlights the importance of peat degradation in Southeast Asia in the global CO_2 budget: combined with earlier estimates of carbon emissions from peatland oxidation[8], it amounts to 0.30 Pg C yr^{-1} averaged over 1997–2006, about a quarter of the updated CO_2 emissions from deforestation and forest degradation. The combined contribution of deforestation, forest degradation and peatland emissions to total anthropogenic CO_2 emissions is about 15% (range 8–20%; see Supplementary Information for a comparison with all anthropogenic greenhouse gases). We conclude that taking into account carbon emissions from peatlands would enhance the effectiveness of REDD programmes, which are under discussion in the United Nation's climate policy negotiations.

In short, the maximum reduction in CO_2 emissions from avoiding deforestation and forest degradation is probably about 12% of current total anthropogenic emissions (or 15% if peat degradation is included) — and that is assuming, unrealistically, that emissions from deforestation, forest degradation and peat degradation can be completely eliminated. Therefore, reducing fossil fuel emissions remains the key element for stabilizing atmospheric CO_2 concentrations.

Nevertheless, efforts to mitigate emissions from tropical forests and peatlands, and maintain existing terrestrial carbon stocks, remain critical for the negotiation of a post-Kyoto agreement. Even our revised estimates represent substantial emissions, and for about 30 developing countries, including Brazil, Bolivia, Indonesia, Myanmar and Zambia, deforestation and forest degradation are the largest source of CO_2 (ref. 17). Moreover, reductions in the emissions from deforestation and degradation of peat and forest may remain one of the more cost-effective 'wedges'[1,23] that can help to stabilize atmospheric CO_2 levels.

If changes in terrestrial carbon storage are to have a role in a post-Kyoto agreement, a strong focus on monitoring changes in carbon content, irrespective of forest cover density would strengthen the effectiveness of REDD programmes. For example, replacing peat forest with oil-palm plantations may not change the tree cover density, but it does lead to a large pulse of CO_2 emissions because of reductions in both tree biomass and soil carbon[8]. In addition to the proposed satellite monitoring of terrestrial biomass, satellite-derived observations of fires as well as measurements of atmospheric CO_2 concentrations in combination with inverse modelling and ground-based validation can help track carbon losses from deforestation and the degradation of forest and peat. ❐

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Additional information

Supplementary information accompanies this paper on www.nature.com/geoscience.