Working Paper Series

13/2008

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This paper was commissioned by the Office of Climate Change as background work to its report 'Climate Change: Financing Global Forests'(the Eliasch Review).

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A first cost benefit analysis of action to reduce deforestation

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September 2008

Abstract

Emissions from deforestation are globally significant. Understanding the benefits and costs of reducing deforestation and forest degradation would allow us to plan a pervasive monitoring, verification and reporting infrastructure as part of a Planetary Skin. The areas most vulnerable to deforestation are mainly concentrated in tropical countries and the bulk of emissions arise when the land is converted to agricultural production (Stern, 2006). While emissions from deforestation contribute significantly to levels of greenhouse gases, there is potential for them to be cut considerably. No new technology is needed to facilitate action and cutbacks could be made relatively quickly. It has subsequently been claimed that curbing deforestation is a highly cost-effective way of reducing greenhouse gas emissions (Stern, 2006). In this paper, we assess the validity of this claim. Using a newly-developed version of the PAGE2002 model, CCPAD, we show the costs and benefits of taking action to reduce emissions from deforestation and forest degradation (REDD). Our results indicate that introducing 50% REDD in 2010 would cost $1.7 trillion (90%CI: $0.7 - $3.3 trillion) and create a mean drop in impacts of $5.3 trillion (90%CI: $0.6 - $17 trillion), bringing a mean net benefit of $3.7 trillion (90%CI: $-0.7 - $14.3 trillion). This positive mean net benefit indicates that REDD actions are viable and worthwhile. We also examine several policy alternatives to assess the costs and benefits of introducing REDD actions after 2010, at varying scales, and on top of aggressive abatement elsewhere. Our results clearly indicate that REDD actions bring higher benefits the earlier, and more aggressively, they are applied.

Introduction

Emissions from deforestation are very significant globally. These emissions could potentially be cut significantly fairly quickly – no new technology has to be developed. The areas of globally significant forest most vulnerable to deforestation are mainly concentrated in tropical countries. The bulk of emissions from deforestation arise when the land is converted to agricultural production. (Stern, 2006)

To deal with climate change we need to make the connection between the global problem – global impacts and the response in terms of limiting global emissions – and the local level where the costs and benefits are experienced and where implementation, design and investment solutions need to be carefully applied. Bridging the two requires a complex "middle layer" in which the global institutional architecture needs to be carefully designed to provide a trusted, credible, verifiable and fungible system of global carbon emission reductions (UNFCCC, 2008). The success of this vital intermediary set of vehicles will rely on the pervasive monitoring and accrediting of emissions at the local level and the broadening and deepening of carbon markets at the global level. The process must draw together a wide array of actors across sectors, institutions and regions in a system that is effective at managing the risks of extreme events and is efficient in minimizing the costs of action by inducing abatement where it is cheapest. In the process it will generate large financial flows between buyers and issuers of carbon credits, with as much as $50-100bn a year flowing to developing countries by 2020 (Office of Climate Change, 2007)

This 'middle layer' can be thought of as an essential global utility. It is required to provide a massive deployment of trusted and reputable open-standards based sensing, authentication, certification, and monitoring capabilities with transparent access, auditability and low transaction costs. These new capabilities would also need to be widely distributed and networked globally so as to be able to incorporate the large but highly fragmented mitigation opportunities across markets and sectors. Extending this concept further we can envision these sensing and monitoring capabilities extended into the critical areas of deforestation, water, biodiversity and food productivity, risk management of nuclear waste and carbon sequestration and storage to mention just a few – to form a Planetary Skin.

Devastation of the world's rainforests is occurring at the rate of one England per year (FAO, 2005) and is the second largest contributor to global greenhouse gas emissions after the power sector (Houghton, 2003). The destruction of this invaluable planetary resource is driven by a number of factors: The links between food, fuel, fibre and forests which have contributed to recent severe food price inflation. This has arisen from land competition between food and fuel, a competition artificially created by short-sighted biofuel policies as well as increases in demand for meat caused by increasing wealth in China, India and elsewhere in the developing world. At the same time we face regional economic development challenges for the 1.6 billion poor living off the forests' natural resources (Chomitz et al, 2006)

The market and governance failures at play here involve many organisations at many levels, from global companies and public institutions to the forest communities themselves. But all conspire to make forests more valuable dead than alive. Reversing this deadly trend will require mechanisms to manage deforestation hotspots by establishing forest property rights so that carbon sequestration services can be priced and marketed. Forest carbon stocks will need to command a predictable price that can compete with food, fibre, fuel and cattle grazing.

To do this it is critically important to understand the drivers of benefits and costs and the associated uncertainties of actionable policies to drastically reduce tropical deforestation and degradation. For this a model is required.

Background to the Cisco Cambridge Policy Analysis of Deforestation (CCPAD) Model

In an earlier paper, we used PAGE2002, a probabilistic integrated assessment model used in the Stern review (Stern, 2006), to calculate the impacts of BAU deforestation on climate change (Hope, 2008). In this paper we use a new version of the model to calculate the costs and benefits of taking action to reduce emissions from deforestation and forest degradation (REDD). We first look at the costs and benefits of 50% REDD starting in 2010 and then compare those costs to two policy alternatives to illustrate the benefits of taking immediate and vigorous action.

Changes to PAGE2002

The standard PAGE2002 model doesn’t allow for declining emission cutbacks in later years (Hope, 2006). Any cutbacks made are assumed to last for ever. As the maximum cutback for REDD could occur as early as 2010, the standard PAGE2002 model would estimate the cost of REDD without taking later REDD policies into account. This is not reasonable, as it is clear that later REDD actions will also bring costs.

The logic for the standard treatment of abatement in PAGE2002 is that it involves capital expenditure that cannot be recouped. – In addition, standard abatement tends to increase with time, so the issue of declining cutbacks rarely arises.

The type of activity necessary for REDD will involve annual payments for as long as deforestation is avoided. So, if the amount of REDD declines, the payments will also decline (Richards and Jenkins, 2007, box 3). This requires a change in the model to remove the constraint that cutbacks cannot decline.

This is done by replacing the equation representing the cutbacks for gas *g*, in analysis year *i* and region *r*:

$$[41] \qquad CB_{i,g,r} = \max\left\{CB_{i-1,g,r}, ZC_{i,g,r} - \mathrm{ER}_{i,g,r}\right\} \qquad \%$$

with a new equation representing the cutbacks in Gtonne instead of % for CO2 (gas *1*):

$$[41] \qquad CB_{i,1,r} = \max\left\{0, CB_{i-1,1,r} + \left(\left(Yhi_i - Ylo_i\right)\cdot\left(ZC_{i,1,r} - \mathrm{ER}_{i,1,r}\right)/100\right)\cdot \mathrm{E}_{0,1,r}/1000\right\} \ \mathrm{Gt}$$

The cost equation is also changed to reflect the new units. The cost of prevention for CO2 (gas *1*), in analysis year *i* and region *r* is

$$[44] \quad PC_{i,1,r} = \left\{\mathrm{CL}_{1,r}\cdot\mathrm{MAX}_{1,r} + \left(\mathrm{CL}_{1,r} + \boldsymbol{if}\ \left(CB_{i,1,r} \le \mathrm{MAX}_{1,r}, 0, \mathrm{CH}_{1,r}\right)\right)\cdot\left(CB_{i,1,r} - \mathrm{MAX}_{1,r}\right)\right\}\cdot 1000 \ \$\mathrm{M}$$

The relevant variables are defined in table 1.

Table 1 variables in the PAGE2002 model affected by the change

Variable	Description	Unit
E	Emissions	Mtonne
ER	Emissions compared to base year	%
Yhi	End of analysis period	year
Ylo	Start of analysis period	year
ZC	Zero cost emissions compared to base year	%
CB	Cutbacks in emissions compared to base year	Gtonne
CL	Costs of cheap preventative action	$M/Mtonne
CH	Additional costs of expensive preventative action	$M/Mtonne
MAX	Cheap cutbacks compared to base year	%
PC	Preventative costs	$M

This change correctly accounts for the costs of the REDD emission reductions for as long as they are implemented. The new model is called the Cambridge Cisco Policy Analysis of Deforestation (CCPAD) model, and is identical to PAGE2002 apart from this change.

Inputs

Deforestation estimates in the main part of this paper are taken from Houghton, 2003. Unit costs of REDD are taken from Kindermann et al, 2008, converted to the annual payment form used in the CCPAD model. It is difficult to see any ‘break points’ that help to define the ‘lower cost’ and ‘extra cost’ ranges as required by the CCPAD model. This means that a large amount of judgement is required to interpret the data in this paper and produce the input values shown in table 2 which are used in the CCPAD runs. All parameter values are independent triangular probability distributions. Taking the most likely values for illustration, the first 30 GtCO2 of emission reductions in Latin America will cost $0.15 per tonne of CO2 per year, and any reductions beyond this will cost $0.60 ($0.15 + $0.45) per tonne of CO2 per year. REDD costs in Asia are 60% of this (but with a larger range, possibly up to twice as costly), while costs in Africa are 80% of those in Latin America. All costs are in year 2000 $US.

Table 2 Unit costs of REDD actions

	min	most likely	max		
CO2 low cost in Latin America	0.06	0.15	0.3	$	per tCO2/yr
CO2 added cost in Latin America	0.3	0.45	0.75	$	per tCO2/yr
Asia Preventative costs factor	0.4	0.6	2		
Africa Preventative costs factor	0.6	0.8	1		

L America low cost CO2 range	15	30	50	GtCO2
Africa low cost CO2 range	40	50	60	GtCO2
China low cost CO2 range	4	8	16	GtCO2
India low cost CO2 range	6	12	24	GtCO2

Source: based on Kindermann et al, 2008

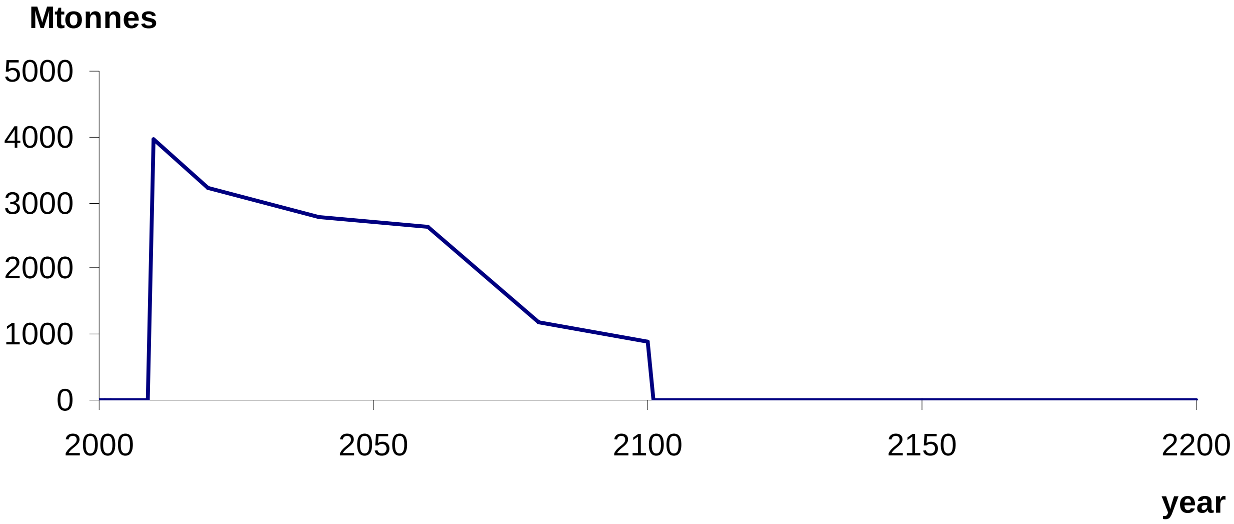
Other emissions are taken from IPCC scenario A2, and all other parameters are as in Hope, 2008. In later sections, results are also calculated with alternative estimates of deforestation and other emissions, to check the sensitivity of any policy recommendations to alternative assumptions.

Results

REDD starting in 2010 at 50% of deforestation

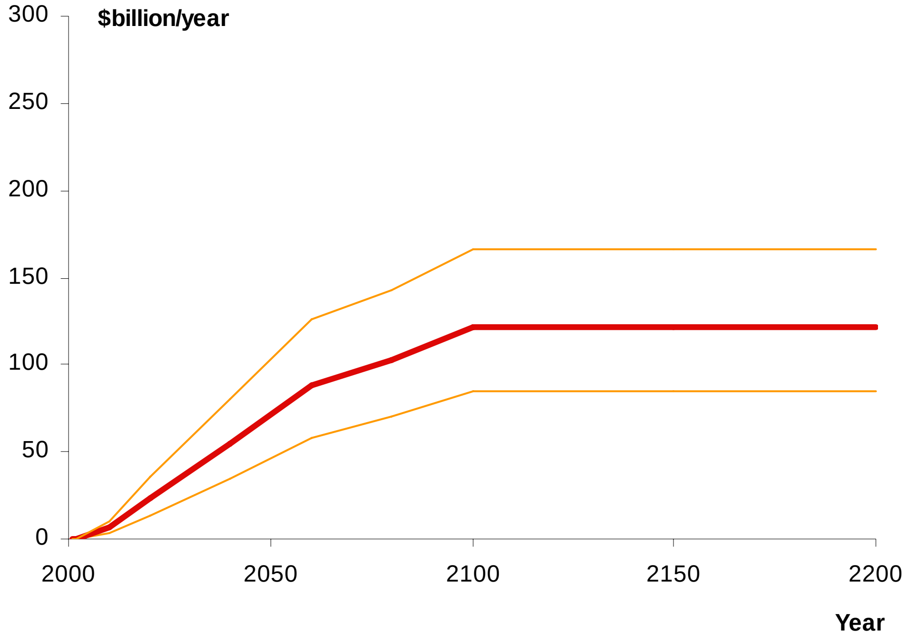
Figure 1 shows the difference in global annual emissions of CO2, with and without the 50% REDD policy starting in 2010. Figure 2 shows that the mean costs of 50% REDD are $39 bn per year in 2030 (90%CI: $24 – 57 bn per year) and rise to $121 bn per year by 2100 (90%CI: $85 - $166 bn per year).

Figure 1 Difference in CO2 emissions of 50% REDD starting in 2010 by year



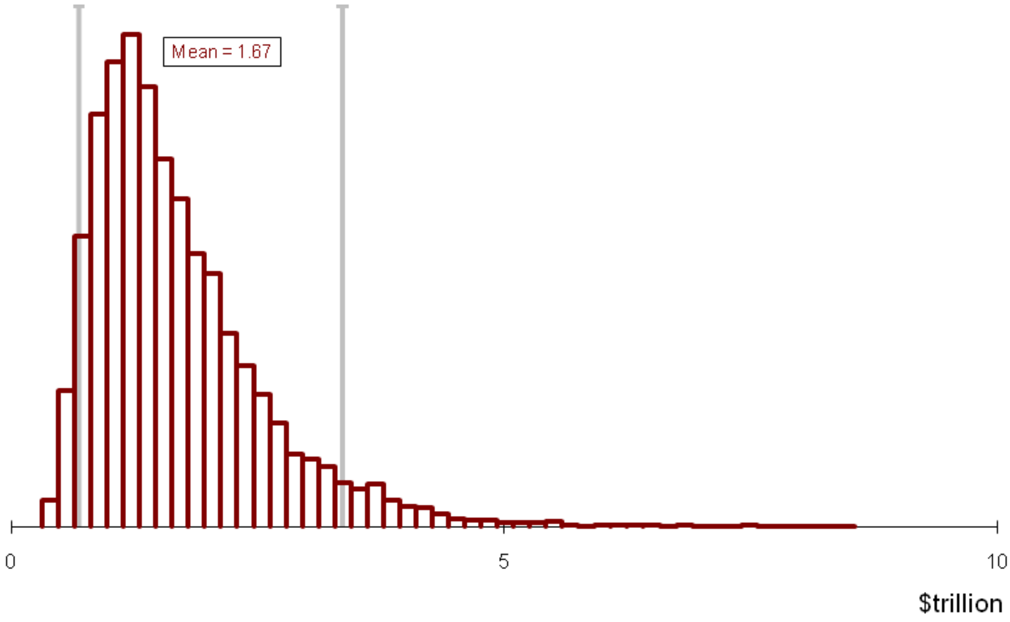
Source: Half of Houghton BAU deforestation estimates from 2010

Figure 2 Costs of 50% REDD starting in 2010 by year



Source: 10000 runs of CCPAD model, half Houghton deforestation from 2010.

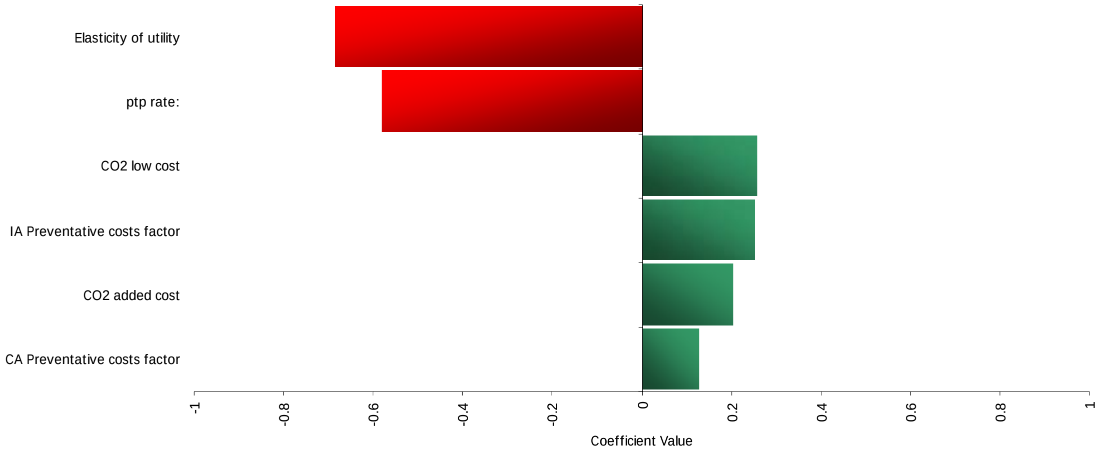
Figure 3 NPV of costs of 50% REDD starting in 2010



Source: 10000 runs of CCPAD model, half Houghton deforestation from 2010.

Figure 3 shows that mean net present value (NPV) of the costs is \$1.7 trillion (90%CI: \$0.7 - \$3.3 trillion).

Figure 4 Major influences on the NPV of costs of 50% REDD starting in 2010

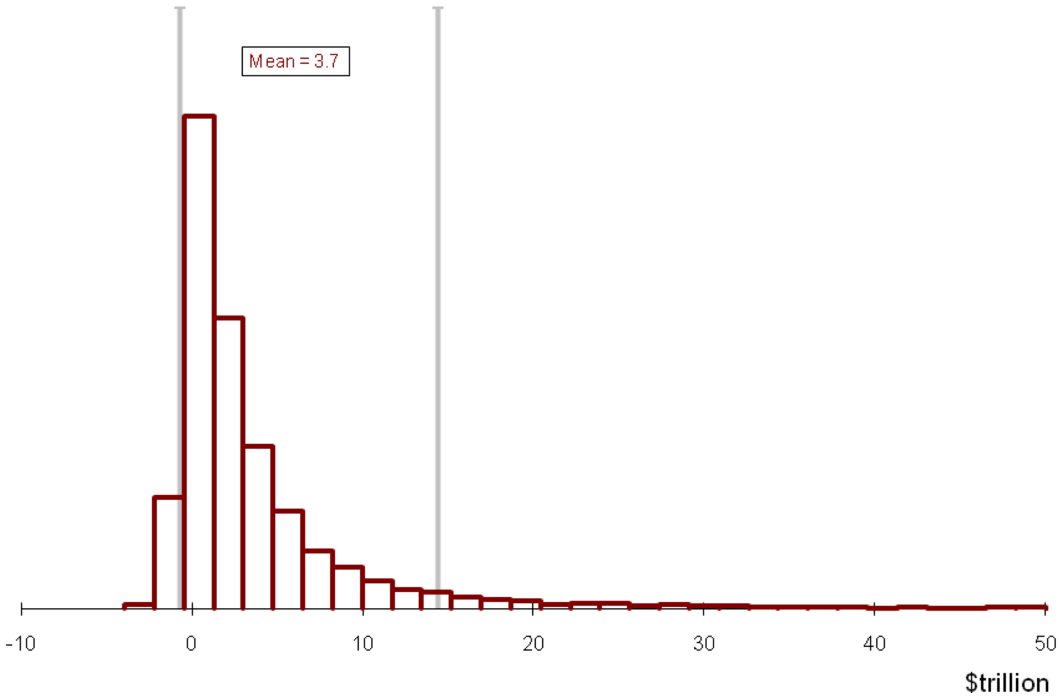


Source: 10000 runs of CCPAD model, half Houghton deforestation from 2010.

Figure 4 shows that the main influences on the NPV of costs are just what one would expect: The initial cost of CO2 reductions is a positive influence, and the elasticity the marginal utility of consumption (through its influence on the discount rate) and ptp rate are negative influences. The CO2 added cost is also important, as, in most tropical regions, 50% REDD takes us into the extra cost part of the curve before the end of the century.

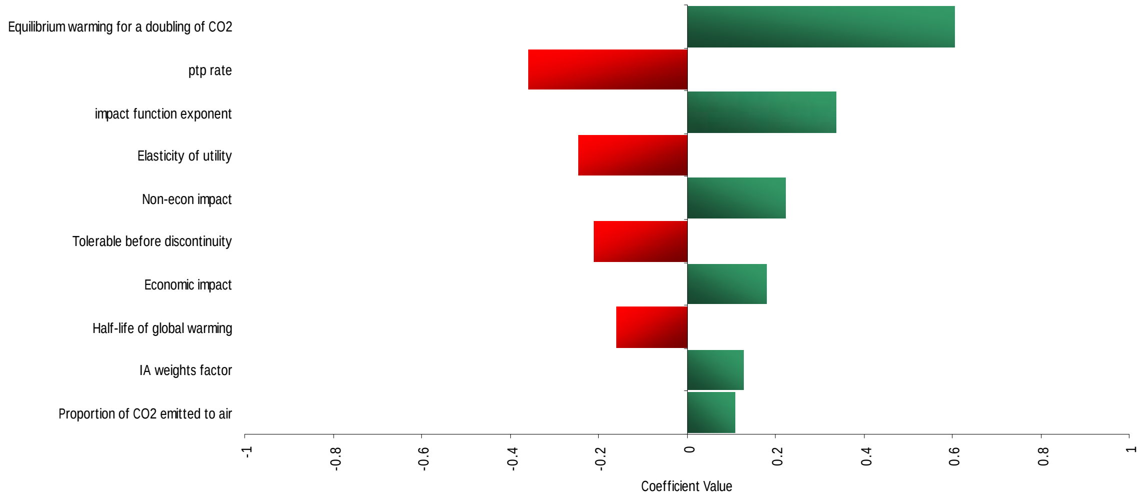
50% REDD buys a mean drop in impacts of \$5.3 trillion (90%CI: \$0.6 - \$17 trillion) when taken from the A2 scenario, bringing a mean net benefit of \$3.7 trillion (90%CI: \$-0.7 - \$14.3 trillion), with an 18% chance that the net benefit is negative, as shown in figure 5. The positive mean net benefit indicates that these REDD actions are worthwhile.

Figure 5 NPV of net benefit of 50% REDD starting in 2010



Source: 10000 runs of CCPAD model, half Houghton deforestation from 2010.

Figure 6 Major influences on the NPV of net benefit of 50% REDD starting in 2010



Source: 10000 runs of CCPAD model, half Houghton deforestation from 2010.

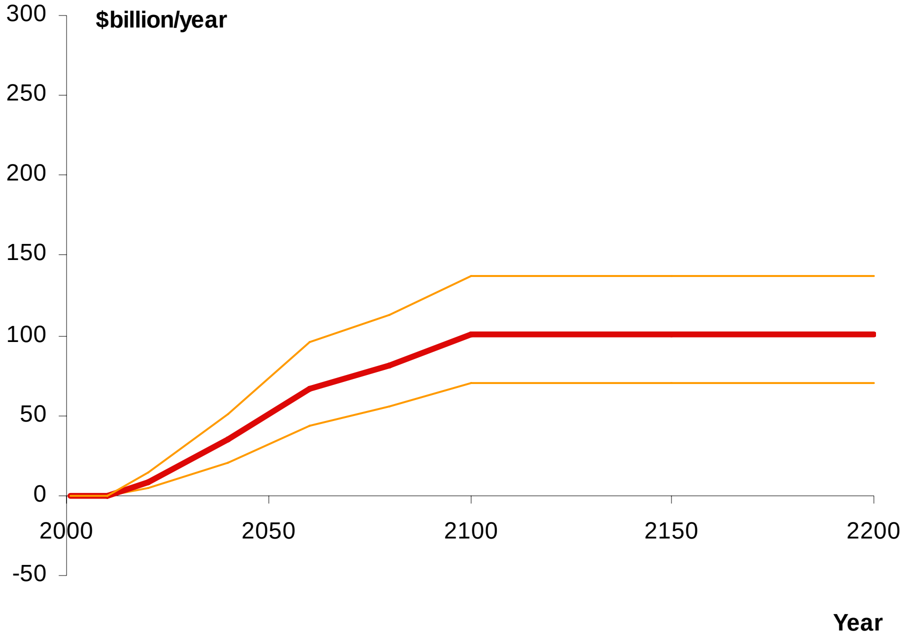
Figure 6 shows that the major influences on the net benefits are influences associated with benefits not costs, as the variation in costs makes very little difference to the net benefit.

Alternative starting date and scale

We also use the CCPAD Model to look at two policy alternatives: 50% REDD that starts in 2020 not 2010, and REDD that reduces deforestation by 90% rather than 50%. This allows us to assess the impact of a later introduction of REDD, and application at a different scale, on the costs and benefits of REDD action.

REDD that starts in 2020

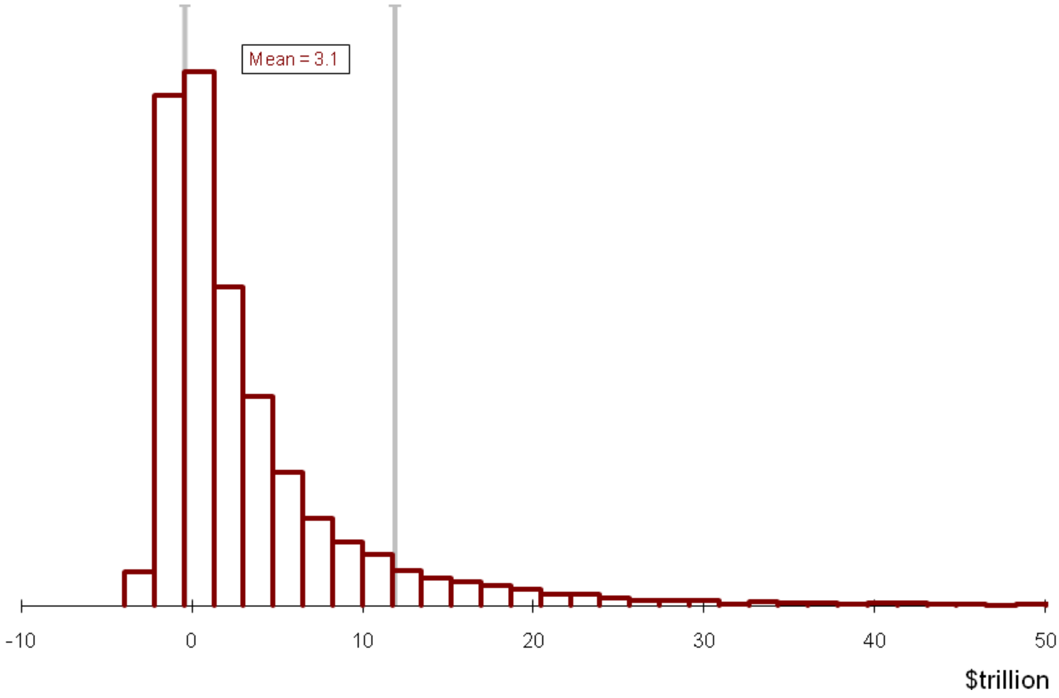
Figure 7 Costs of 50% REDD starting in 2020 by year



Source: 10000 runs of CCPAD model, half Houghton deforestation from 2020.

Figure 7 shows that the mean costs of 50% REDD that starts in 2020 are $21 bn per year in 2030 (90%CI: $12 - $32 bn per year) and rise to $100 bn per year by 2100 (90%CI: $70 - $140 bn per year). The ten-year start delay reduces costs by almost half in 2030, but only by about one sixth in 2100. Mean discounted costs are $1.2 trillion (90%CI: $0.4 - $2.2 trillion), about $500 bn lower than costs for 50% REDD that starts in 2010.

Figure 8 NPV of net benefit of 50% REDD starting in 2020

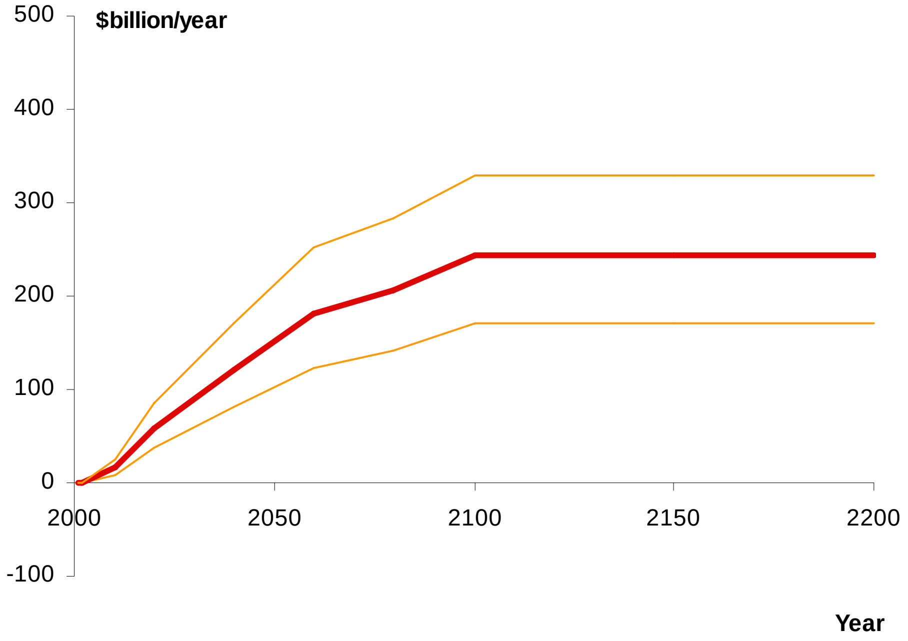


Source: 10000 runs of CCPAD model, half Houghton deforestation from 2020.

50% REDD from 2020 buys a mean drop in impacts of $4.3 trillion (90%CI: $0.5 - $14 trillion) when taken from the A2 scenario, bringing a mean net benefit of $3.1 trillion as shown in figure 8, (90%CI: $-0.4 - $12 trillion), with about a 15% chance that the net benefit is negative. This net benefit is about $500 bn lower than the net benefit of 50% REDD that starts in 2010, clearly showing that it is not beneficial to delay implementing REDD.

REDD at 90% of deforestation

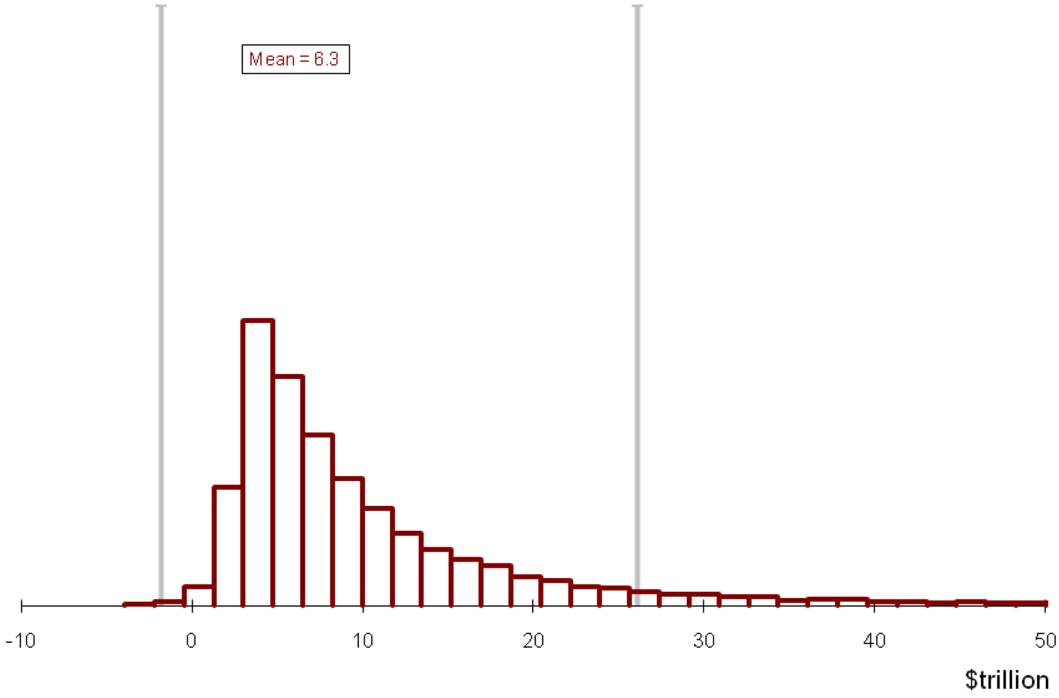
Figure 9 Costs of 90% REDD by year



Source: 10000 runs of CCPAD model, 10% of Houghton deforestation from 2010.

Figure 9 shows that the mean costs of 90% REDD rise to \$90 bn per year in 2030 (90%CI: \$60 - \$130 bn per year) and \$243 bn per year by 2100 (90%CI: \$170 - \$330 bn per year). This is slightly more than twice the cost of 50% REDD because part of the cost of 50% REDD is in the low cost part of the Marginal Abatement Cost (MAC) curve. Mean discounted costs are \$3.5 trillion (90%CI: \$1.5 - \$7 trillion). These costs compare with other estimates of the associated opportunity, protection and transaction costs of \$ 40-70 billion per annum up to 2050 for action to reduce deforestation by 95% (Strassburg et al, 2008).

Figure 10 NPV of net benefit of 90% REDD



Source: 10000 runs of CCPAD model, 10% of Houghton deforestation from 2010.

These costs of 90% REDD buy a mean drop in impacts of about $10 trillion (90%CI: $1 - $30 trillion) when taken from the A2 scenario. So, with these input data, 90% REDD also looks to be very worthwhile, bringing a mean net benefit of $6.3 trillion with a 25% chance that the net benefit is negative, as shown in figure 10. This mean net benefit is $2.6 trillion higher than for 50% REDD, so if the choice is between 50% and 90% REDD, 90% REDD should be chosen.

Alternative estimates of deforestation

Although all estimates suggest that land use emissions are significant, estimates of the scale of land use emissions vary widely (Stern, 2006). The Third Assessment Report of the IPCC estimated present emissions from land use change as being within the range equivalent to 2.2 to 9.9 GtCO2, with a central estimate of 6.2 GtCO2 (Baumert et al, 2005).

Figure 11 shows an alternative projection of BAU deforestation to 2100, from the IMAGE model (Strengers et al, 2004). Its profile is very different to the Houghton estimates used up to now, although the cumulative emissions over the century are quite similar.

Figure 11 Two estimates of BAU deforestation by date

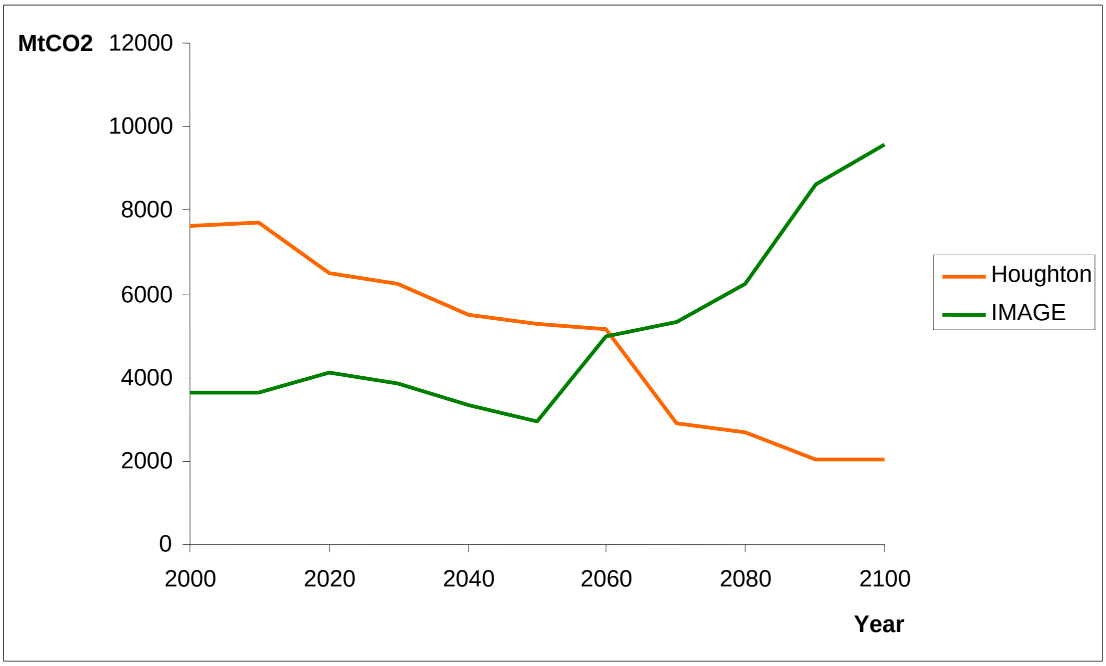
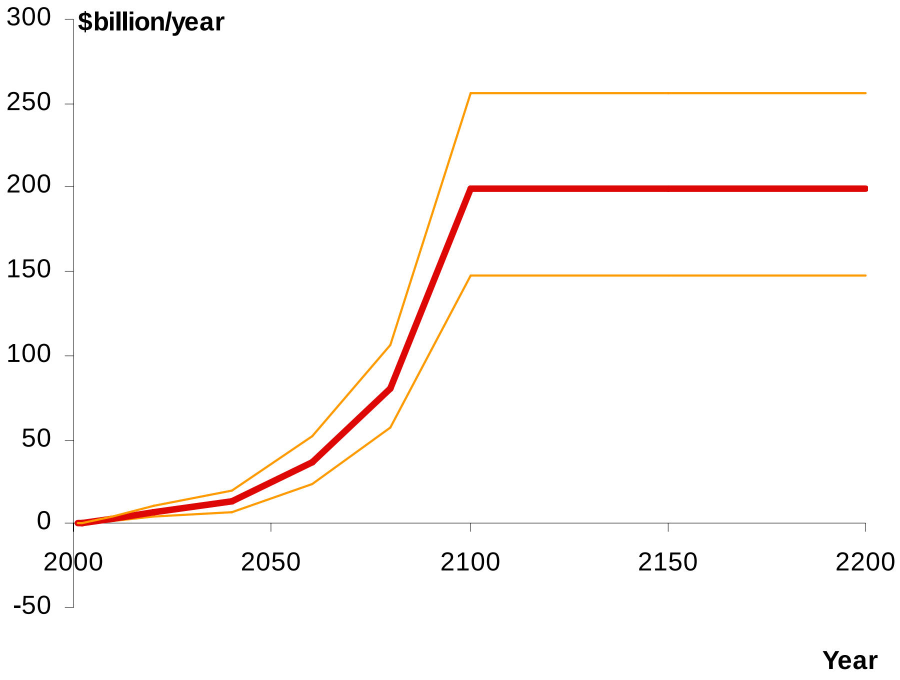


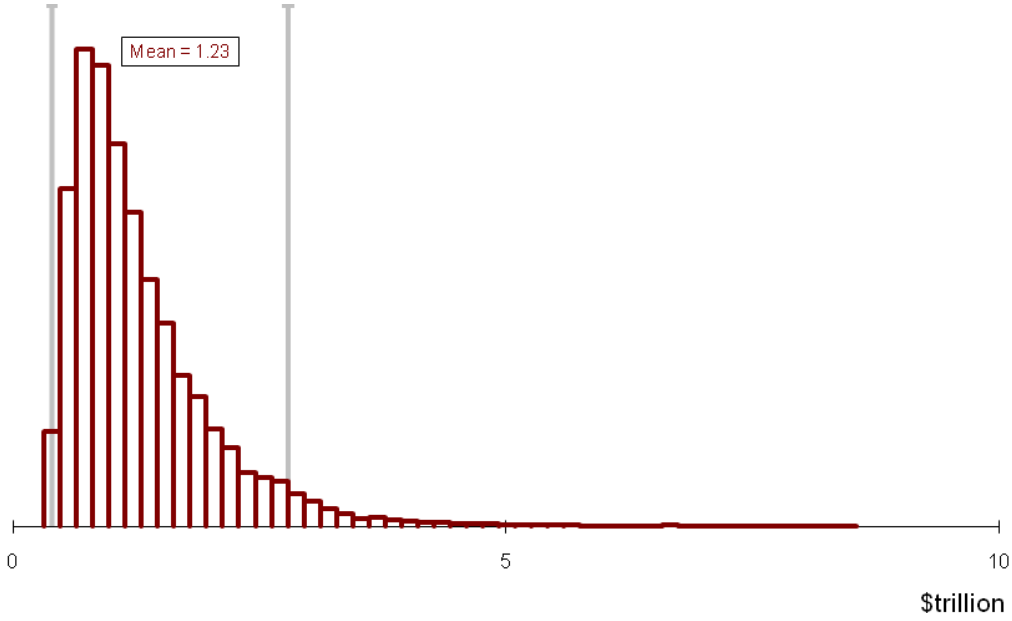
Figure 12 Costs of 50% REDD with IMAGE deforestation by year



Source: 1000 runs of CCPAD model, half IMAGE deforestation from 2010.

Figure 12 shows that mean costs of 50% REDD with IMAGE deforestation are $10 bn per year in 2030 (90%CI: $5 - $15 bn per year), rising to $200 bn per year by 2100 (90%CI: $150 - $250 bn per year). As might have been expected from the deforestation profiles, these are only about one quarter of the costs of deforestation in 2030 with Houghton estimates, but about two thirds higher than costs with Houghton figures for deforestation in 2100

Figure 13 NPV of costs of 50% REDD with IMAGE deforestation

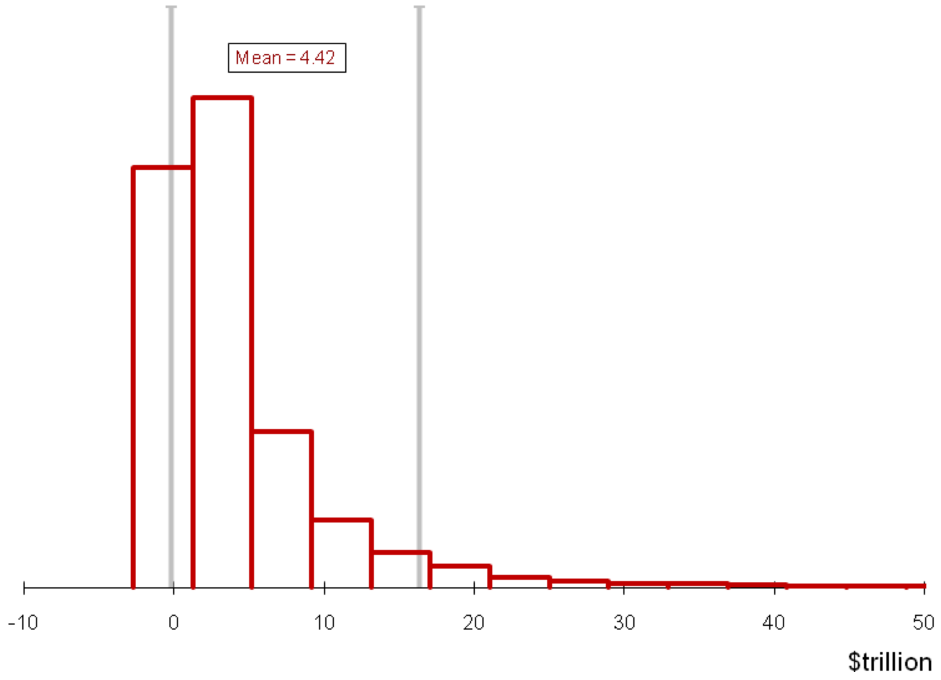


Source: 1000 runs of CCPAD model, half IMAGE deforestation from 2010.

Figure 13 shows that the mean discounted costs of 50% REDD with IMAGE deforestation are $1.2 trillion (90%CI: $0.4 - $2.8 trillion). This figure is about three quarters of the costs calculated with Houghton deforestation.

50% REDD with IMAGE deforestation buys a mean drop in impacts of $5.6 trillion (90%CI: $1 - $20 trillion) when taken from the A2 scenario, bringing a mean net benefit as shown in figure 14 of $4.4 trillion (90%CI: $-0.2 - $16 trillion), with only a 9% chance that the net benefit is negative. This is about 20% higher than the net benefit of REDD calculated with Houghton deforestation. Despite the very different profile of deforestation, the net benefit of taking action to reduce it by 50% is very similar. This lack of sensitivity gives extra assurance that REDD actions are worthwhile.

Figure 14 NPV of net benefit of 50% REDD with IMAGE deforestation



Source: 1000 runs of CCPAD model, half IMAGE deforestation from 2010.

Deforestation with aggressive abatement

As well as the SRES A2 non-intervention scenario, the Houghton estimates of deforestation can be combined with an emission path that reflects a strenuous attempt to limit CO2 concentrations, for instance a path of CO2 emissions designed to produce a 450 ppm CO2 concentration using the MAGICC model (Wigley, 2003). This combination can be used to check whether the impacts of deforestation, and therefore the value of REDD actions, are sensitive to actions that are taken in other parts of the economy to reduce greenhouse gas emissions

Under this ‘450’ scenario, the NPV of impacts with the Houghton estimates of deforestation is, on average, about $12 trillion higher than without deforestation, with a 5 – 95% range of about $1.5 to $40 trillion. This is the best estimate we have of the impacts of BAU deforestation under an aggressive abatement path of other emissions, such as the ‘450’ scenario (Hope, 2008). It is practically identical to the value under the A2 scenario, which in this paper leads to a reduction in impacts of $5.3 trillion (90%CI: $0.6 - $17 trillion) for 50% REDD starting in 2010.

As the non-intervention A2 scenario and the ‘450’ scenario enclose the full range of plausible emission paths over the next century, we can conclude that the impacts of BAU deforestation are almost totally insensitive to the emissions scenario on which they are superimposed. The greater increase in global mean temperature caused by the deforestation emissions in the ‘450’ scenario is counterbalanced almost exactly by the non-linear relationship of impacts to temperature. This relationship will make a given temperature increase cause a smaller rise in impacts if it is added to a lower base, such as the ‘450’scenario, rather than a higher one, such as the A2 scenario.

Consequently, all of the cost benefit results in this paper apply not only to REDD actions taken in non-intervention scenarios like scenario A2, but equally to actions taken in combination with aggressive abatement of other emissions. REDD actions are a highly cost-effective way of reducing CO2 emissions, and they bring higher benefits the earlier and the more aggressively they are applied.

This high return opportunity is ripe for innovation at the failing edge of the market through the creation of a ‘rainforest skin’, the first set of carbon flux and stock monitoring capabilities of the Planetary Skin, an open network platform for real-time, highly distributed mass remote sensing, certification and monitoring of carbon stocks and flows that generates trust and enables collaboration between the actors in all three sectors. This platform would use a combination of geo-referenced satellite, unmanned aerial vehicle and multiple ground based sensor networks to estimate the forest’s carbon stock and flow dynamics and then allow for trading and risk management of this new commodity. Shifting the calculations of risks and opportunities in this way will remain central to maintaining the world’s capacity to avoid crossing dangerous climate thresholds.

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