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The theoretical battlefield: Accounting for the carbon benefits of maintaining Brazil's Amazon forest

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Abstract

The way that carbon accounting is done greatly influences the value attributed to maintaining tropical forests. Accounting choices will be determining factors in the role that Brazil's Amazon forest plays in global mitigation efforts and in the role that funds from mitigation will play in redirecting the course of history in Amazonia. Critical decisions include the form of accounting (stocks *versus* flows) that are applicable under different circumstances, baselines for establishing additionality, and the restrictions and adjustments (including discounting to attribute value to time) applied to reflect differences in permanence, leakage and uncertainty. None of these problems is insurmountable, but addressing them will require both academic effort and the political courage of decision makers to act on available information.

Keywords: baselines; carbon; discounting; ecosystem services; environmental services; global warming; leakage; mitigation; PES; rainforest; permanence; tropical forest; uncertainty

1. Introduction

Maintaining Brazil's Amazon forest has substantial climate benefits in two areas: evapotranspiration, which supplies water vapor responsible for rainfall in much of Brazil and neighboring countries [1, 2] and the large stock of carbon in the forest's biomass [3, 4] and soil [5-7]. These carbon stocks would make an important contribution to global warming if released as greenhouse gases [8, 9]. Release of carbon can occur either deliberately through deforestation and logging or unintentionally through forest fires and forest dieback provoked by climate change. The environmental services that the forest provides represent a major resource that could provide an alternative to the present economy in the region, which is almost entirely based on destroying the forest [10-13]. Carbon benefits are the closest to providing the basis for monetary rewards for forest maintenance, and these benefits are the focus of the present paper. Reducing Emissions from Deforestation and Degradation (REDD) is the most recent descriptor for these efforts. A long list of outstanding issues must be resolved if monetary rewards are to be implemented on a significant scale. The present paper outlines issues involved in accounting for climate benefits; choices of accounting procedures can have a substantial effect on the financial rewards of forest maintenance. Additional issues related to what is done with the money and to the place of Amazonia in ongoing international negotiations are treated separately [14].

The question of rewarding the climate benefits of maintaining Amazonian forest has long been a source of controversy. One battlefield in this debate has been over quantifying the physical parameters, such as carbon stocks, deforestation rates, and emissions (reviewed in [15-17]). A second battlefield involves an evolving series of largely political issues in the international negotiations [14, 18, 19]. The third battlefield is a theoretical one, involving how accounting is done. This is the subject of the current brief review.

Before examining the various challenges of accounting for the carbon benefits of maintaining Amazonian forests, it should be recognized that the entire enterprise of

trying to quantify and account for these benefits has been attacked at various levels, including all three "battlefields." One line of reasoning holds that forest values are of a moral or sacred type and should not be subject to any form of accounting [20-22]. This argument holds that no form of financial reward should be given to forest maintenance for carbon, or even for other forms of "offsets" including wind or solar investments to substitute for fossil energy. A profound revolution of society is seen as paramount and carbon accounting and trading are considered to be obstacles. As Gilbertson and Reyes [22, pp. 89-90 & 102] put it, "ultimately carbon trading is a means to preempt and delay the structural changes necessary to address climate change" and "the struggle against climate change has to be part of the larger fight for a more just, democratic and equal world." While I am a wholehearted supporter of justice, democracy and equality, I am not able to justify abandoning available mitigation tools in the interests of hastening a more general revolution in society. The considerable body of scholarship developed by proponents of the anti-accounting viewpoint contains many valuable insights on the weaknesses of accounting procedures and institutional arrangements for carbon management.

Another segment of opinion would deny any reward for forest maintenance but would support subsidies for wind, solar and a variety of other means of reducing net carbon emissions [23]. The place where mitigation actions would occur is the reason for criticism, the argument being that "It [REDD] … takes the focus off of the need for countries historically responsible for the climate crisis to reduce emissions at home" [24, p. 14]. This confuses two different questions: who should pay and where the mitigation should be done. That rich countries should pay the bulk of the cost is widely accepted, but that the mitigation must be done "at home" is another matter. Mitigating in Europe, for example, is substantially more expensive per ton of carbon than is the case for mitigation through REDD in tropical countries, even if sizeable deductions are made in the benefits attributed to REDD in order to allow for uncertainty, leakage, and lack of permanence. The result of restricting mitigation to the wealthy countries is that each ton of carbon kept out of the atmosphere costs more, and, since no country currently has a binding quota (assigned amount) for its emissions after 2012, these countries will simply not agree to cutting their net emissions by as much as they would if cheaper options were available. In addition to the emissions quotas, also lacking agreement is the related issue of defining the concentrations of greenhouse gases that correspond do the 2°C average global temperature increase over pre-industrial levels that has now been agreed as "dangerous interference with the climate system" that must be avoided under Article 2 of the United Nations Framework Convention on Climate Change [25]. With more expensive carbon, countries will negotiate to set the definition of "dangerous" at a higher concentration level, and will thereby be free to emit more gases. The higher the agreed atmospheric concentrations, the greater the probability that the 2°C temperature level will, in fact, be exceeded [26]. A disproportionate part of the impact of this will fall on places like Brazil (*e.g.*, [27]).

The clamor for mitigation "at home" is couched in moral terms, as a sort of repentance for past emissions that have brought us to a climate crisis (*e.g.*, [24]). However, from the point of view of governments other factors have greater explanatory power. If the money to be spent on mitigation is used within a European country such as Germany, for example, it would go to such measures as producing wind turbines and solar panels and to retooling industries such as automobile

factories. All of this would produce income and employment in Germany. On the other hand, if the response were to send the money to Brazil to stop deforestation this would do nothing for the economy of Germany. Avoiding tropical deforestation will therefore only be supported for token amounts, even though the climate benefit per unit of money invested is probably much greater than mitigation "at home" [19].

While both of the lines of argument against REDD attack the difficulty of accounting, the conclusion that these difficulties provide justification for abandoning or blocking efforts to proceed with REDD in tropical forest areas such as Amazonia appear to be founded on the desire to attain objectives other than rapidly containing global warming. In both cases the opportunity to maintain Amazonian forest, with all if its environmental services (including carbon storage), is being sacrificed in deference to other objectives. The environmental and social cost of allowing Amazon forest to be lost, both through continued deforestation and degradation and through climate change, is enormous (*e.g.*, [17, 28]). The present author therefore does not share either of the viewpoints that would abandon or severely restrict efforts to apply funds from carbon benefits to maintaining the Amazon forest and its human population. Carbon accounting questions should not be seized upon as an excuse to discard forest maintenance as a mitigation option: instead these issues should be faced and appropriate decisions made in establishing the rules for rewarding forest maintenance.

2. Stocks *versus* flows

A recurrent question is how to demonstrate "additionality," or showing that a reduction in carbon emissions only occurs due to a mitigation project and would not have happened in the absence of the project. This stems from the provision in the Kyoto Protocol that "reductions in emissions are additional to any that would have occurred in the absence of the certified project activity" [29, Article 12, Parag. 5]. Establishing that a reduction in emissions is "additional" requires comparison of the observed emissions with the emissions that are calculated to be what would have occurred in the absence of the project. This requires agreement on a hypothetical (counterfactual) baseline scenario to represent what "would have happened." The procedure for quantifying flows can be either "stock change" (also called "stock difference": the difference between before and after estimates of carbon stocks on the site) or "loss-gain" (calculation from measurements of rates of tree growth and mortality) (*e.g.*, [30]).

An alternative to flow-based accounting is accounting based on stocks (not to be confused with the "stock change method for estimating flows). Prior to the Kyoto Protocol adopting an accounting based on changes in flows, this author proposed carbon calculations based on stocks [10]. This would treat the stock of carbon, for example in Amazonian forest, in a manner similar to the balance in a bank account. Interest would be earned annually as a percentage of the value of the stock, rather than based on the change in the stock. Obviously, destroying the stock would sacrifice future revenues. Both forms of accounting require a baseline against which comparison can establish changes. The advantage of the stocks-based approach is that it allows crediting for maintaining forest where little forest destruction has taken place in the past. If the baseline for a flows-based accounting is historical deforestation, as is the tendency under the current negotiations, then areas with little or no previous

deforestation can get no credit and those actors who have been destroying the forest in the past are effectively rewarded for their bad behavior. Interest in stocks-based accounting has recently resurged in Brazil's state of Amazonas, where the state government's "Amazonas Initiative" rewards environmental services in protected areas where flows-based accounting would not indicate a climatic benefit [31].

The objection is often raised that rewarding carbon stocks in tropical rainforest would oblige the world to pay for stocks of fossil carbon in Chinese coal or Saudi oil. However, there are fundamental differences between forests and fossil fuels that justify not rewarding fossil fuel stocks. Fossil fuels stay in the ground unless they are actively removed: there is no need to pay a guard to stand at every oil well in order to keep the oil in the ground. Tropical forests, by contrast, require continual active defense, often by the traditional peoples who inhabit them rather than by government guards.

Other solutions have also been proposed to address the difficult issue of guaranteeing that a substantial portion of the funds to be derived from mitigation will go to areas far from the current deforestation frontier. One would be to use the "plus" feature of "REDD+", meaning REDD with additional consideration for social benefits and for non-carbon environmental services such as biodiversity maintenance. This would direct funds to activities that increase a basket of different benefits, rather than the process being guided solely by the search for cheap carbon. Another possibility would be to have some sort of division of effort between mitigation based on reduction in flows and that based on stocks. The protection of areas with high biodiversity requires mechanisms to channel REDD activities to these areas. If the cost per ton of carbon is the only criterion, most opportunities for biodiversity protection would be lost [32, 33]. This is especially so if carbon accounting is based solely on flows. The tradeoff involved in incorporating biodiversity and other factors into decisions on REDD+ has limits, as reflected in the argument by Patternayak *et al.* [34] for "far fewer competing side objectives". It should be remembered, however, that carbon stock protection in Amazonia has so far been a free rider on actions in other spheres: the largest area of forest under some form of protection is in indigenous areas that are created on the basis of human rights, followed by conservation units that are created on the basis of biodiversity. Striking a proper balance between carbon and other REDD benefits is the subject of ongoing debate (*e.g.*, [35-39]). Although the myth is crumbling that all camps can be satisfied with "win-win" solutions, in many cases modest reductions in carbon benefits can result in large gains for biodiversity and traditional peoples.

The Institute for Environmental Research in Amazonia (IPAM) and the Woods Hole Research Center (WHRC) have put forward a promising series of proposals for integrating benefits for both flows and stocks into a reward system [40, 41]. This began with the "stock-flow mechanism" for distributing benefits across countries [42]. The mechanism can also be applied within a country such as Brazil to distribute benefits across categories, which may be either states or land types such as indigenous reserves, conservation units, settlements and a grouping that, because of the chaotic land-titling situation in Amazonia, lumps private and public land [40]. The mechanism operates under the principles of the "nested approach" [43], whereby the total reduction and its reward are apportioned between countries, subnational units or other levels such that no double counting occurs. At the global level, the total amount of funds available for reducing deforestation and degradation is distributed, with the

funds divided into two channels: one compensates reductions in the flow (avoided emissions) and the other compensates maintenance of stocks (a dividend per ton-year of carbon maintained in forest biomass or soil.

The division between the two channels could be done based on fixed proportions or by an equivalent mechanism based on a "carbon price" (either based on international markets or as determined by an international fund). The "carbon price" is multiplied by the total global reduction in deforestation and degradation emissions below the global baseline; this amount goes to compensate flows, and the remainder of the total funds available for REDD goes to compensate stocks. For the flow portion of the pie, the amount going to each country (or other unit) is based on the observed deforestation emission as compared to a historical baseline in that country, and the same principle applies if the division continues to sub-national units or to land-use categories. Since the global baseline and the total global emissions reduction are both derived by summing from the lower hierarchical levels, the result is a complete allocation of both carbon and money.

If countries fail to keep forest emissions below their respective baselines, then they are penalized by creating a carbon debt that would have to be paid off by reducing emissions below the baseline in subsequent years before receiving any revenue from REDD. A weakness in the system might arise if a country takes the benefits when deforestation is going down, but subsequently when deforestation is going up the country's government decides that it is politically unattractive to control deforestation and simply allows the felling to rebound, giving up any intention of later paying off the carbon debt to restart the REDD benefits. Such a scenario is not entirely unrealistic for Brazil, where deforestation has declined well below the country's proposed baseline since 2006, but where extensive plans for building roads and dams in Amazonia and a national congress dominated by "ruralists" (representatives of large landholders) sets the stage for future increases in deforestation [44].

Under the stock-flow mechanism, the portion of the benefit pie that goes to rewarding stocks is apportioned among countries (and to any units within them) in accord with the proportion of the total stock of forest carbon present in each country or other unit. This reward of stocks is essential to keep low-deforestation countries in the game, along with important actors within the countries such as the indigenous peoples in Brazil whose lands contain 27% of Brazilian Amazonia's carbon stocks ([40], p. 134). Other proposed formulations that are restricted to flows, such as the "compensated reductions" approach [45], target only high-emissions countries, while modifications that direct some of the benefit to low-emissions countries (e.g., [46, 47]) pay a price in economic efficiency (carbon-flow reduction per dollar spent) without gaining another valuable environmental service, such as that represented by stock maintenance [42].

The proposed stock-flow mechanism has been supplemented with an additional feature to become "stock-flow with targets" [48]. This adds a "bonus" to the reward for countries (or other units) that succeed in achieving emission-reduction targets: the reductions achieved beyond the specified target level generate the full value of the additional emissions reduction, without deducting the withholding amount that finances the stock portion of the mechanism as is the case for the

emission reductions that occur at levels below the target. The flexibility that this adds allows the reward structure to be manipulated such that essentially all tropical forest countries would find it to be in their economic interest to join in the REDD program. The targets and bonuses, as is also the case for the "carbon price" and other parameters determining the allocation, are subject to political negotiations among the countries or sub-national units involved. Evidently, the fairness, the environmental and social co-benefits, and the magnitude of the emissions reduction achieved will depend on the outcome of these negotiations.

3. Baselines

The "baseline" is the hypothetical no-project scenario against which the real-world results with a mitigation project will be compared in order to quantify additionality and carbon benefits. The list of considerations involved is extensive [49-55]. There are multiple ways by which there can be "gaming" of baselines, meaning constructing an argument for the hypothetical no-project scenario that exaggerates the carbon benefits to be claimed by the project. This can involve exaggeration of the carbon stocks and the emissions from land-use conversions, counting changes that would occur anyway as part of the project benefits, and ignoring leakage and other drains on project benefits. The Kyoto Protocol's Clean Development Mechanism (CDM) has been plagued with scandals involving carbon credit being given to non-additional projects of every description [21, 56]. Examples include the crediting of hundreds of hydroelectric dams that would have been built anyway in virtually all cases, in addition to having their greenhouse emissions ignored or grossly understated [57, 58]. Avoided deforestation is not among the project types included in the CDM for the 2008-2012 First Commitment Period of the Kyoto Protocol because this form of mitigation was ruled out in the Bonn agreement of July 2001. Had avoided deforestation projects been included, the same types of scandals could easily have applied. Substantial tightening of the system is needed for this and all types of projects in the periods from 2013 onwards or under future climate agreements.

The normal way of "gaming," or manipulating, a baseline involves exaggeration of the initial level of emissions, such that what is found to be emitted in subsequent years will be lower than the baseline, or at least will have grown by less relative to the baseline than would otherwise have been the case. The United Nations Framework Convention on Climate Change (UN-FCCC) called for all countries to make an initial inventory for the standard base year of 1990. Brazil chose a range of years instead (1988-1994). The first Brazilian inventory [59] underestimated the countries emissions in multiple ways, especially for land use, land-use change and forestry (see [8]). The question often arises as to why such a bias would be introduced, since it eliminates future revenue that might be gained should Brazil decide to take on a commitment under the Protocol and sell carbon credit from reducing deforestation. Brazil's first inventory omits such items as tree roots and dead biomass and chooses many parameter values that minimize net emissions (see [8]). It is relevant to remember that at the time the first inventory was being compiled the idea of any sort of compensation for reducing Amazonian deforestation was anathema to the Brazilian foreign ministry, and that anything that would avoid possible pressure on the country to reduce its deforestation and emissions, or to take on a commitment under the Protocol, was a top priority [18, 60, 61]. Brazil's negotiating positions changed in 2007 to support payments to the country through a voluntary fund based

on reductions below a baseline calculated as the mean of deforestation over five-year intervals. The 1996 -2005 period used as the baseline for the first of the five-year intervals had an average deforestation rate of 19,508 km^2/year [62], a value much higher than the current rate of clearing. This creates the potential for payments for "hot air," or non-additional claims of carbon benefits [44]. The second inventory eliminates some of the obvious low biases of the first inventory, such as omitting below-ground biomass and assuming wildly optimistic rates of carbon uptake by secondary forests [63].

The baseline chosen for Brazil's Amazon Fund begins high for the 2006-2010 period: 19,507.85 km^2/year, this being the average historical deforestation rate over the 1996-2005 decade. The original plan was for the baseline to decrease in five-year steps through 2020, as proposed by the National Plan for Climate Change ([62], p. 12). However, the current plan is for the Amazon Fund's baseline rate to be used as a target for the 2011-2015 period is to use the average deforestation rate for 2001-2010, which was 16,531 km^2/year ([64], p. 39), rather than the 11,705 km^2/year foreseen in the original National Plan for Climate Change ([62], p. 12). The new target is more than double the 2011 deforestation rate and allows ample leeway to gain credit in the 2011-2015 period even if the deforestation rate increases tremendously: the average rate in the next four years could be as high as 26,440 km^2/year without completely losing credit. Furthermore, if an upturn of this magnitude were to occur the target level for 2016-2020 would then become the same 16,531 km^2/year level, a far cry from the 5735 km^2/year target for that period foreseen in the original National Plan for Climate Change ([62], p. 12), or the 3806 km^2/year rate suggested in a subsequent proposal by the Ministry of the Environment ([65], p. 28). About half of the decline in deforestation since the 1996 -2005 initial baseline was already evident at the time the Amazon Fund was proposed in December 2008, but the subsequent continuation of the decline could not have been foreseen. In practice, the effect of an unrealistically high initial baseline is partially compensated by a purposely low assumption of a 100 t ha^{-1} carbon stock, or about 50% lower than the true stock. However, in 2012 the Ministry of the Environment is gathering data for a future revision of the carbon stock value, which implies raising it to a more realistic level and eliminating the cushion against hot air from the baseline choice.

The ease of gaming baselines to inflate the resulting additionality makes historical baselines most attractive because the past history of deforestation cannot be changed (errors and biases in reporting not withstanding), whereas a computer simulation of future deforestation can easily be manipulated. There is an inherent potential bias in reports from consulting firms hired by mitigation project proponents to estimate carbon stocks and simulate baselines. The potential for bias is the same as that for Environmental Impact Assessments (EIAs) in Brazil, where the role of project proponents in paying for the studies gives them tremendous influence over the content of the reports, with the result that the reports invariably find minimal impacts for the proposed projects (see [66]). A solution that can minimize potential biases in mitigation proposals without being restricted to historical baselines is to use baselines that have already been published in the peer-reviewed literature by groups that were not being funded by the project proponents. This was the argument used in the case of the Juma project in Amazonas [67], which based its baseline scenario on a simulation of future deforestation by Soares-Filho *et al.* [68]. However, even in this case the

baseline chosen indicated substantially higher deforestation by 2050 than is likely to occur [69]. Use of peer-reviewed literature does not serve as a guarantee against choosing a baseline that is overly favorable to the project proponents, as there is often a range of published projections from which to choose, creating the inherent temptation to choose the most favorable one.

While use of historical baselines is appropriate in some cases, in others it can result in awarding credit for "hot air," or carbon credit without any real climate benefit (*e.g.*, [70]). Deforestation in any given location takes place in three distinct phases. In the first phase, the deforestation process is just beginning and no previous historical deforestation exists, meaning that no credit can be gained based on a historical baseline. In the second phase deforestation is rapid, there has been a substantial amount of past deforestation and there is still plenty of forest left to clear; this is the phase in which additionality can produce reasonable results. In the third phase deforestation is slowing down because the area of forest available for clearing is dwindling. In this case, "hot air" will be produced by the additionality criterion, since deforestation is bound to decrease below historical levels without any help from the mitigation program.

4. Leakage

"Leakage" refers to climatic benefit being negated by changes induced outside of the boundaries of a mitigation project [71, 72]. This can occur, for example, if a protected area is established and those who would have deforested in the protected area simply move to another part of the forest and continue clearing. There can also be more diffuse economic leakage, where the economic activity (such as logging or agricultural production) is displaced to some distant location by means of price signals in the economic system [73, 74]. International movement of major corporate actors, such as those trading soybeans, could also produce leakage [75]. Various solutions have been proposed for dealing with different circumstances. For example, "leakage contracts" were negotiated with logging companies in the case of the Noel Kempff Mercado project in Bolivia, where companies received compensation for halting logging in a reserve and formally agreed not to reinvest in logging elsewhere [76, 77].

Charging the emissions impacts to consumers in countries that import soy and beef from Amazonia has been proposed as a measure that avoids leakage, among other benefits [78]. Development of the economic models needed to allocate emissions to consumers is advancing rapidly throughout the world [79]. If restrictions in either producer or consumer countries are put in place through quotas or taxes these would indirectly result in charging consumers through the higher prices they would pay for timber, beef, soy or other products that destroy tropical forests. Any system that did not work through such a price mechanism would be very difficult to implement.

For leakage from protected areas, the key question determining the loss of climate benefits is accounting for the value of time [80]. Leakage from a protected area can be of two types. "In-to-out" leakage occurs when people who had been living in an area that is made a reserve move out of the new reserve and continue their clearing elsewhere in the forest. "Out-to-out" leakage occurs when actors, such

as landgrabbers (*grileiros*) (see [81]), are moving into the general area of the reserve from distant locations. Had the reserve not been created, some of these new arrivals would have settled in the reserve and deforested, but after the reserve is created they will almost always choose to establish themselves in other locations in the forest where the chances of gaining a land title are greater than they are in a reserve. Out-to-out leakage, which is ignored, for example, in the Juma carbon project, is probably the more important of the two types in the context of Brazilian Amazonia, where proposals focus on forest reserves that include their present inhabitants, such as "sustainable development reserves" in the state of Amazonas. In either in-to-out or out-to-out leakage, the loss of benefit for climate continues until available forest in the landscape outside of the protected area has all been cleared, at which point the lost benefit is recuperated because deforestation cannot advance into the reserve. The number of years needed to reach this point and the value attached to time determine the effect on carbon benefits from the reserve [80].

Proposed policy remedies for leakage often do not apply to Brazil, where the major forces driving deforestation differ from those in many other parts of the world. Complementing avoided deforestation projects with initiatives to subsidize nearby plantations [82], for example, would help in a situation where deforestation is driven by demand for firewood, but not where the forces at play respond to commodities like beef and soy or to a mix of factors such as land speculation, money laundering and land tenure establishment (see [81, 83]). Overall declines in Brazilian deforestation from 2005 to 2007 are well explained by beef and soy prices (including exchange-rate effects), but from 2008 to 2010 the effect of increased government expenditures on command-and-control repression predominated [84, 85]. Investment in control would be a better option, since past history indicates that it can have a measurable effect on Amazonian deforestation and because confidence in the government's ability to contain forest loss is essential to the entire effort to avoid deforestation [86].

Another measure that has been proposed to limit leakage is to restrict the amount of mitigation that can be done through avoided deforestation [82]. This is similar to the cap placed on Clean Development Mechanism (CDM) credits from "sinks" in the Marrakesh Accords of 2001 [87]. This would limit the total amount of emission reduction that could be lost to leakage, but it would also limit the benefit that could be obtained for climate, as well as for biodiversity, traditional peoples and other values of maintaining tropical forest.

The effect of leakage at the project level, as in the discussion above, can be avoided by doing mitigation and accounting at the level of a country or of a region (such as Amazonia) [73]. In addition, the broader policies that affect deforestation at these levels can be more effective in reducing clearing than can geographically-limited projects. The "jurisdictional approach," or focusing on larger political units, is gaining favor in discussions of REDD in future arrangements under the Climate Convention, but projects are the focus of today's voluntary carbon market.

5. Uncertainty

Uncertainty, especially the probability of climate benefit being less than the calculated amount, is a key element in discussions of the value of mitigation through avoided deforestation. The uncertainty associated with these projects is inherently

greater than is the case for reductions in emissions from fossil fuels. How any adjustment for this difference is made, and what criteria are used to admit or exclude proposed projects, can have a great effect on the scale that forest-sector mitigation plays [88-90].

The notion that very high levels of certainty should be demanded as a precondition for any carbon crediting is counterproductive from the point of view of maximizing the expected impact of mitigation investments on the levels of greenhouse gases in the atmosphere. As in any investment, the "expected monetary value" (EMV) is equal to the sum of the net value of all possible outcomes multiplied by their respective probabilities of occurrence. In this case, the possibility of a very large reward or "jackpot" if major reductions in deforestation do, in fact, occur means that even substantial levels of uncertainty do not make the expected value unattractive [91].

One proposal for correcting for uncertainty would adjust credit downward (sometimes called "discounting", not to be confused with discounting for time) for each ton of avoided emission within a range of emission values around a baseline or expected emission [92]. The adjustment would be greatest near the baseline and would decline progressively the further the observed emission is below the baseline, becoming zero after passing out of the range identified as encompassing probable emission levels without mitigation. A refinement of this proposal would have the width of the band decrease over time [79].

Brazil's monitoring capabilities with remote sensing are a key element in lending credibility to avoided deforestation efforts in the country [93-95]. These capabilities have in the past been subject to various forms of selective and tendentious use [15], and unresolved technical issues remain [96]. However, the system has become much more transparent in recent years [97]. In addition, an independent remote-sensing option (a collaboration between Google and various non-governmental organizations) will soon allow participation of civil society in providing ground verification of data on deforestation (and potentially also forest degradation) [98]. Advances in remote sensing promise to reduce uncertainties in tropical forest monitoring [99-103].

Semantic debates over defining forest and deforestation pose additional risks. "Zero illegal deforestation" is the long-range objective of the Amazon Fund that the Brazilian government has established to receive donations from other countries [63]. However, this could be achieved in various ways other than by reducing deforestation. One has only to make the existing deforestation "legal" by revising the forestry code to permit a greater percentage of deforested area. Another way would be to redefine "transition" forests as savannas instead of forests. Both of these are current proposals from the "ruralist block" (members of the National Congress who represent the interests of large landholders) (*e.g.*, [104, 105]). Another point of discussion is the Mato Grosso state government's insistence that areas should be considered to still be in "forest" even if they appear on satellite imagery as open but where this is the result of all but a few scattered trees having been killed by forest fires rather than by deliberate clearcutting.

The definition of forest, and hence of deforestation, is limited by FAO [106], and consequently IPCC [107] definitions, having included "temporarily unstocked" areas as "forest." This means that an area can be counted as "forest" if the site has no trees because it has been cleared as part of a shifting-cultivation cycle, or for any other reason, so long as there is an intention of allowing tree cover to regrow in the future. Since intentions cannot be detected by satellite, this loophole represents a barrier to independent monitoring of avoided deforestation.

Methods for estimating forest biomass and carbon stocks have been classed into three "tiers" by the IPCC [108], the third tier representing information with georeferenced land cover information from remote sensing and information on per-area stocks and related factors that are local or at least based on measurements in the same country. Certainty levels for REDD will require at least this level of information (*e.g.*, [109]).

6. Permanence

One of the great unresolved issues is treatment of time in calculating mitigation benefits. This is the basis of controversies over "permanence," or the time carbon remains out of the atmosphere. Valuation of this requires decisions both on the time horizon and on the value attributed to time, as through a discount rate [110, 111]. One line of reasoning holds that anything less than permanent carbon removal from the atmosphere is either a "distraction from the actual job of mitigating climate change" [112] or is simply worthless (*e.g.*, [113]). However, strong arguments support giving value to temporary storage of carbon, appropriately adjusted for a value of time greater than zero [114-117].

Various alternatives have been proposed to deal with the issue of permanence, including ton-year accounting ([118]; see [119], pp. 87-89). A "ton-year" refers to a unit of one ton of carbon remaining in (or out) of the atmosphere for one year. Ton-year accounting can faithfully reflect global-warming impacts under different mitigation scenarios if the focus of attention is on the period up to the time horizon (for example, for the next 100 years), but does not work if judged by effects beyond this horizon [120]. There are two types of ton-year accounting, one focusing on the carbon in the trees, known as the "Moura-Costa method" [121] and the other focusing on the carbon in the atmosphere, known as the "Lashof method" (see [118]). The second system has the advantage of allowing a discount rate or other weighting for time preference to be applied, thus opening the way for a much-needed explicit incorporation of time preference in carbon accounting [110, 111]. Ton-year accounting has garnered little support among carbon project developers because the rewards are delayed in time [122]. However, the "pay-as-you-go" approach also has the advantage of guaranteeing that the carbon befits are real. It is natural that carbon entrepreneurs would prefer to have a large up-front payment in exchange for some sort of promise of permanence, even if the financial advance would have to be refunded and/or penalties would have to be paid at some future time in the absence of permanence.

Another means of dealing with permanence is the "Colombian proposal" for temporary credits ([123]; see also [124]) that is currently in use by the CDM for granting credit for carbon in silvicultural plantations [125]. In this system temporary

credits (temporary certified emissions reductions: tCERs) are granted for carbon in afforestation and reforestation only (natural forest maintenance is excluded from the CDM until after 2012), and when the temporary credit expires it will have to be replaced either with a permanent credit or another temporary one.

A way to adjust mitigation decisions for varying degrees of permanence through "fractions of permanence" has been by Dutschke [126]. This draws from both the ton-year approach and the Colombian proposal's temporary credits to propose leasing reduction certificates.

Market mechanisms assign a value to permanence when temporary credits are offered for sale, indicating a "discount" of approximately 50% at present but with the potential, depending on future carbon prices, to render impermanent carbon worthless [127]. The problem is that leaving the value of time to be decided by the discount rates applied by carbon traders, whose decisions are based on comparisons with the financial returns available from investment opportunities elsewhere in the economy, surrenders the key factor determining what forms of mitigation will take place. The Intergovernmental Panel on Climate Change (IPCC) special report on land use, land-use change and forestry put it well: "the consequences of allowing choices on global warming decisions to be determined by discount rates that are derived in other spheres could be severe" ([119], p. 89).

Carbon accounting that effectively gives no value to time is dangerous in the context of Brazilian Amazonia. Although not a universally held viewpoint, in Europe (particularly) one often encounters the idea that reducing deforestation is a mere "distraction" that should be avoided so that pressure can be allowed to build up more quickly on the industrialized countries to invest in technologies such as wind turbines and solar panels (*e.g.*, [24]). The implication is that any measure that can't guarantee that carbon will remain out of the atmosphere permanently is worthless, and that we have plenty of time to wait for green energy technology to develop for "real" mitigation. Unfortunately, Amazonia can't wait because a variety of 'tipping points' are likely to be crossed if global warming is allowed to continue (*e.g.*, [28, 128-134]). While general circulation models of future climate contain substantial uncertainty as to the timing and severity of increased droughts, a large majority of existing models indicate Amazonia as becoming dryer [135]. It should be noted that the UK Meteorological Office's Hadley Centre model, which has traditionally had the most catastrophic results for Amazonia, indicates less drought in the model's most recent version [136].

Amazon forest would not survive either more frequent droughts like those of 1997-1998 and 2003 provoked by El Niño events from warming in the Pacific Ocean, or droughts like those of 2005 and 2010 caused by warmer water in the Atlantic Ocean [128, 137-139]. The consequences of climate-induced savannization in Amazonia would be catastrophic for Brazil, implying, among other things, loss of the forest's biodiversity and its role in water cycling that maintains rainfall in the heavily populated south and central regions of the country (*e.g.*, [28]). It also implies loss of the forest's role as a carbon stock that avoids the worldwide impacts of a substantial jump in global warming.

Slowing tropical deforestation is one of the measures that can be done most quickly and most inexpensively per ton of carbon emission avoided [140, 141]. Equally important is the fact that tropical deforestation affects a globally significant amount of carbon. Brazil is the key country because it has by far the largest stock of remaining tropical forest [106]. Slowing deforestation in Brazil also represents a substantial opportunity because this is a goal espoused by the Brazilian government independent of its role in global warming, therefore greatly increasing the likelihood that major reductions can be achieved if a serious investment is made. Neither Brazil's economy nor the livelihood of any significant share of the country's population depends on the large cattle ranches that account for most of the destruction of Brazil's Amazon forest [142].

7. Future perspective

Maintaining Brazil's Amazon forest offers a major opportunity in global efforts to mitigate global warming. Decisions on carbon accounting represent political choices that determine financial rewards, mitigation effectiveness, and collateral effects. Choices are needed that avoid crediting fictitious claims of carbon benefits, that contribute to maintaining biodiversity and that direct resources to traditional people who maintain the forest. This requires attention to the type of accounting (flows versus stocks) applicable under different circumstances, the means of determining baseline scenarios, and appropriate corrections for differences in certainty and for the value of time, which is the key factor in translating between temporary and permanent carbon and in assessing the importance of leakage.

International climate negotiations have proceeded slowly, although progress toward agreement on REDD+ has been greater than in other areas. The underlying accounting issues of the choice of a basis (stocks versus flows), baselines, leakage, uncertainty and permanence must be faced and solved in such a way as to allow Amazon forest maintenance to be supported on a large scale. In the rush for rapid agreement, the temptation is strong to leave these issues unresolved and sweep them "under the rug." The result would likely be to minimize damage to the overall objective of containing global warming by placing a restrictive cap on the amount of mitigation that can be done by forest maintenance. This outcome would waste a major opportunity to achieve agreement on deeper cuts in global emissions and to maintain large areas of Amazonian forest with their people and multiple environmental services intact.

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Executive summary

1.) Stocks versus flows

Change in a carbon flow is the current basis for accounting under the Kyoto Protocol, which does not yet reward avoided deforestation and degradation in tropical forests.

Rewarding the maintenance of carbon stocks is a potential alternative basis for accounting for Amazonian carbon. Flows-based accounting in Brazilian Amazonia would tend to reward large ranchers and soy producers, whereas stocks-based accounting would reward indigenous and other traditional residents of the region's interior. Stocks-based accounting would support creation of large reserves at low per-hectare cost far from the deforestation frontier, whereas flow-based accounting would lead to protecting small areas at high per-area cost near the frontier.

Solutions must be found, via the accounting basis or other means, to apply a substantial portion of mitigation funding to forests far-removed from the current frontiers. Long-term climate benefits would be greater as well as contributions to maintaining the region's biodiversity and traditional population.

2.) Baselines

Baselines, or hypothetical "no project" scenarios against which real emissions will be compared, are easily manipulated to create fictitious carbon benefits or "hot air" (in flows-based accounting).

Historical baselines, which are based on extrapolation of documented past deforestation, are hard to manipulate. However, they are only applicable at an intermediate stage in the deforestation process.

For areas where deforestation is advanced, clearing rates will slow anyway and the historical baseline will produce “hot air.”

For area with little previous deforestation, the historical baseline will indicate little or no future clearing and no credit can be generated to support forest conservation.

Technical improvement, transparency and independence of project proponents are necessary for modeled baselines to be credible for these areas.

3.) Leakage

“Leakage,” or effects on emissions outside of the boundaries of a project, can negate the benefits of measures such as reserve creation.

Leakage can be from local, national or international movement of deforestation and degradation activity, including not only physical movement of actors but also effects transmitted through price signals in the global economy.

Leakage subtracts from the benefits of a reserve on the short term, but on the long term this loss will be recaptured when areas outside of reserves are effectively cleared. The value attributed to time (as through discounting) is critical to determining the loss to leakage and the ultimate benefit of the reserve.

4.) Uncertainty

The possibility that climate benefits could be less than what is calculated means that credit claimed needs to be adjusted downward accordingly.

The minimum degree of certainty demanded needs to recognize the tradeoff between the certainty demanded and the possibility of capturing major gains for mitigation.

Changes in Brazil’s Forest Code and varying definitions of forest create uncertainty concerning future emissions.

Uncertainty is being reduced by better monitoring and quantification of the stocks and flows of carbon.

5.) Permanence

Delaying emissions has value for mitigating climate change even if the avoided emission is not permanent.

Different forms of ton-year accounting have been proposed to translate between permanent and temporary carbon.

Another way of dealing with nonpermanent carbon is to allow the market to assign prices to temporary credits (tCERs), as is currently done for silvicultural plantations under the Kyoto Protocol's Clean Development Mechanism.

The value attributed to time, as through a discount rate (whether assigned by the market or by a negotiated decision) is the critical factor determining the value attributed to Amazonian forest.

Projected threats to Amazonian forests from deforestation and climate change mean that time has a great value in applying major funding to forest maintenance.

Key terms

Leakage

Effects, especially losses, outside of the geographical, temporal or conceptual boundaries of a mitigation project. For example, creating a forest reserve may lead people to move or settle elsewhere in unprotected forest and continue clearing at the same rate.

Baseline

A hypothetical scenario for calculating future emissions without a mitigation project or activity. The emissions in this scenario will be compared with the actual emissions determined from monitoring the mitigation project.

Additionality

The carbon benefit as calculated by subtracting the observed emissions from the baseline emissions. This difference is considered "additional" to what would have occurred without the mitigation project.

Permanence

The time that carbon remains out of the atmosphere. Fossil fuel carbon is considered to be permanent, whereas carbon in forests can be released at a future time.

REDD and REDD+

Reduced emissions from deforestation and degradation. The "+" in REDD+ refers to non-carbon environmental services such as water and biodiversity, as well as social benefits.

Time preference

The value given to time, whereby events (such as carbon emissions) in the future have less weight than those in the present. This is usually included in calculations by applying a discount rate, the choice of which can radically change the value given, for example, to maintaining Amazonian forest. Time preference is the “elephant in the room” for carbon accounting.