CHAPTER 19

MITIGATION OF CLIMATIC CHANGE IN THE AMAZON

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INTRODUCTION

Amazonian forests and climate change

Mitigation of climatic change in tropical forests has become one of the most controversial subjects in conservation. National governments and non-governmental organizations (NGOs) have taken varying positions on mitigation measures such as planting trees and avoiding deforestation. These positions have also changed over time, sometimes abruptly, in response to political agendas. As I will argue here for Brazilian Amazonia (Fig. 1), avoided deforestation has far the greatest potential both for climatic benefits and for achieving other environmental objectives such as maintenance of biodiversity.

A clear distinction must be made between funding motivated by biodiversity concerns and that motivated by climatic-change mitigation. In this chapter, I argue that mitigation through avoided deforestation (which is entirely justifiable solely on the basis of society's willingness to pay for climatic benefits) can play an important role in maintaining Amazonian biodiversity—not that the much smaller pool of biodiversity funding should be hijacked for the benefit of climate-mitigation efforts.

The opportunity for climate mitigation to counter the powerful economic forces that threaten Amazonian forests lies in the much greater willingness of interested parties at present to pay for avoiding climate change as compared to avoiding biodiversity loss. As a binding international agreement, funding for climate-change mitigation via the Kyoto Protocol is expected to be much larger than could reasonably be expected from voluntary "public-relations" carbon projects financed by the private sector. For example, planners in the 1993-2001 Clinton administration were expecting that, over the 2008-2012 period, the U.S. would spend US$8 billion annually on purchasing carbon credits (J. Seabright, Brazil/U.S. Aspen Global Forum on the Kyoto Accords, Colorado, 9-11 October 1998). At that time, prior to the G.W. Bush presidency, the U.S. was expected to represent about half of the global carbon market in the 2008-2012 period. While the withdrawal of the Bush administration from Kyoto negotiations for the 2008-2012 period greatly reduces the potential carbon market on that time scale (as does the 2001 Bonn agreement, which eliminates avoided deforestation as a mitigation measure from 2008-2012), the magnitude of potential monetary flows on a longer time scale makes mitigation a major opportunity for conservation. Key decisions will be negotiated in 2005. The issue is therefore a very current one, and the decisions to be made cannot be taken for granted.

Mitigation and adaptation strategies

"Mitigation" refers to measures to reduce the amount of climate change, as distinguished from "adaptation," which refers to protecting, moving, or changing human and natural systems to accommodate climatic changes with a minimum of disruption. Global warming is a major worldwide concern caused by net emissions of greenhouse gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Most emissions come from burning of fossil fuels, but about 30% come from land-use change in the tropics, especially deforestation (Fearnside 2000a). Land-use changes release greenhouse gases from burning and from decay of biomass, as well as from soil changes, cattle, and hydroelectric dams.

In addition to its impact on global warming, deforestation also provokes climate change by diminishing the supply of water vapor from evapotranspiration, thereby reducing rainfall in Amazonia and in the heavily populated central-south portion of Brazil (Salati and Vose 1984, Fearnside 2004, Marengo et al., in press). Also, changes in the boundary layer above deforested areas in Amazonia can produce teleconnections that reduce summer rainfall in North America and elsewhere (Avissar et al., chap. 2). Furthermore, aerosols in the smoke released by biomass burning impede rainfall formation by providing an excessive number of cloud-condensation nuclei, thereby forming water droplets that are too small to fall to the ground as rain (Rosenfeld 1999). Reduction of deforestation therefore mitigates a variety of climatic changes by avoiding atmospheric emissions and other land-use-change impacts.

In addition to avoiding deforestation, global warming can also be mitigated by planting trees in areas without trees. Atmospheric carbon is sequestered by being incorporated into tree biomass, and, depending on whether the wood is harvested and what products are derived, the carbon is maintained out of the atmosphere for variable amounts of time. Unfortunately, in current discussions about mitigation measures, a variety of land-use options have been lumped into the term "sinks," including temporary sequestration of carbon in biomass and wood products, permanent displacement of fossil carbon by substitution of coal or oil with wood or charcoal, and avoided emissions from slowing deforestation. Most criticism of "sinks" focuses on the first of these categories, silvicultural plantations.

Tropical forests in the Kyoto Protocol

Under the Kyoto Protocol, or under any alternative agreement that may take its place, credit for reducing emissions of greenhouse gases will be sold between nations, such that at least part of the emissions in highly industrialized parts of the world can be offset by reductions achieved at lower cost (and often also with greater collateral benefits) in other parts of the world. One way of reducing emissions that could generate such credits for sale is by reducing deforestation in Amazonia.

Avoided deforestation can be achieved in various ways. One way is at the project level, where specific activities can be shown to restrain or discourage clearing in an area. Protected area establishment and defense is one type of such project, while efforts to implant licensing and inspection programs are another. Project-level approaches are subject to varying degrees of "leakage," or the negation of project benefits by changes that the project induces outside of its defined boundaries. Projects must include measures to minimize these effects, and to quantify and correct credit allocations for those that remain. Another set of options applies to programs, usually at the national level, rather than to individual projects (Fearnside 1995a). These measures are independent of most leakage effects, as any movement of deforestation activity that individual measures provoke within a country will not affect emissions totals at the national level. Program-level measures also escape the difficult task of showing a causal link to specific project activities, thereby greatly increasing the amount of credit that can be claimed. The downside is that these options require national-level emissions commitments, but, as will be discussed later, Brazil's national interests could be best served by embracing such a commitment and exploiting its advantages for much larger amounts of credit for avoided deforestation.

Prior to negotiation of the Kyoto Protocol in December 1997 (UN-FCCC 1997), there was wide agreement that both planting trees and avoiding deforestation were important measures in the fight against the greenhouse effect. In 1989, the German Parliament (Bundestag) held a series of hearings on tropical forests and global climate change (in which I twice testified), and produced a report that identified slowing tropical deforestation as a key priority for reducing global warming (Deutscher Bundestag 1990). In 1992 a major new initiative, the Pilot Program to Conserve the Brazilian Rainforest (abbreviated as "PP-G7"), was approved by the G-7 industrial countries. Reducing emissions of greenhouse gases from deforestation was one of its principal purposes (e.g. World Bank 1992, Brazilian Ministry for Environment 2003). I served as a member of the PP-G7's International Advisory Group for nine years (1993-2001), during which the G-7 countries donated over US$250 million to the program; by far the largest contributions were made by Germany, followed by the U.K. Major European environmental NGOs such as Greenpeace (Leggett 1990) and Friends of the Earth-UK (Myers 1989) published reports in which both planting trees and reducing tropical deforestation were forwarded as high priorities in the fight against global warming.

However, soon after the Kyoto Protocol was signed in December 1997, the European governments and European-headquartered NGOs abruptly turned against all forms of "sinks," including avoiding tropical deforestation. This anti-sink stance stemmed from a circumstance unique to the Kyoto Protocol's first commitment period (2008-2012), for which the emissions quota for each of the industrialized countries was fixed at the time of the Kyoto conference in 1997—before key decisions had been made, such as whether projects to reduce deforestation in tropical countries would be included in the Clean Development Mechanism (CDM). This circumstance presented a one-time opportunity for European countries to advance other agendas related to competition with the United States, where fossil fuel prices are approximately half those in Europe (see Fearnside 2001a). If the doors could be effectively closed to purchase of significant quantities of carbon credits from projects in developing countries, then the United States would be forced to sharply increase its domestic fossil fuel prices in order to reduce emissions to the quota agreed in Kyoto, thereby leveling the competitive playing field with Europe.

A parallel logic underlay the attraction of European NGO members to opposing "sinks": resentment of the United States for its various sins in the world, including that country's role as the largest single emitter of greenhouse gases and its repeated obstruction of progress in climate negotiations. Environmental NGOs headquartered in Europe, such as Greenpeace, Friends of the Earth, Worldwide Fund for Nature, and Birdlife International, split sharply over the issue with those headquartered in North America, such as Environmental Defense, Conservation International, The Nature Conservancy, the Natural Resources Defense Council, and the Union of Concerned Scientists. In Brazil, credit for avoided deforestation was supported by both grassroots and research NGOs, including the Amazonian Working Group, the National Council of Rubbertappers, the Coordinating Body of Indigenous Peoples of Brazilian Amazonia, the Federation of Agricultural

Workers, the Pastoral Land Commission, the Institute for Man and the Environment in Amazonia, the Institute of Environmental Research of Amazonia, and the Socio-Environmental Institute (Fearnside 2001a, 2001b). In both the United States and Brazil, branches and affiliates of European-headquartered NGOs, such as Greenpeace, Friends of the Earth, and the World Wide Fund for Nature, followed the European line in opposing credit for forests, with one important exception: Friends of the Earth-Brazilian Amazonia (e.g. Monzoni et al. 2000).

In the wake of the stunning withdrawal by U.S. President George W. Bush on 13 March 2001 from negotiations for the Kyoto Protocol's first commitment period (2008-2012), an agreement was reached by the remaining countries in Bonn in July 2001, ruling out avoided deforestation for credit (which could formerly have occurred under the Clean Development Mechanism [CDM] in the first commitment period; UN-FCCC 2001). Despite disagreements, prospects are much improved for agreement on avoided deforestation as a mitigation measure under the CDM beginning with the Protocol's second commitment period (2013-2017), with negotiations to begin in 2005. Inclusion of forest is likely because the underlying motivation of the European opposition does not apply to the second commitment period, as the emissions quota for each country in the second period has yet to be negotiated. Because the net reduction in emissions to which each country's negotiators will agree is limited by the cost they foresee as needed to achieve the target, the existence of relatively inexpensive means of compliance means that negotiators will agree to deeper cuts in net emissions. Allowing a large source of low-cost credit from avoided deforestation therefore means that the countries will agree to reduce their emissions by more, and if forests are excluded the countries will simply agree to reduce by less.

Brazil's official opposition to crediting avoided deforestation stems from a completely different logic from that of the Europeans. Unlike the Europeans, who opposed all "sinks," the negotiating position of the Brazilian Ministry of Foreign Affairs has so far been to oppose credit for avoided deforestation, but to argue for approval of credit for silvicultural plantations. The opposition to credit for avoided deforestation stems from a fear among Brazilian diplomats that deforestation is uncontrollable, and that Brazil could become subject to pressures that would jeopardize its sovereignty in Amazonia, if carbon credit were accepted and the country subsequently failed to control deforestation (Fearnside 2001c, see also Council on Foreign Relations Independent Task Force 2001). The individualistic nature of these opinions is clear from the generalized support for carbon credit in other parts of Brazilian society, including all of the state governments in the Amazon region (see Fearnside 2001a, IPAM et al. 2000). Indeed, the former governor of the Brazilian state of Amazonas, Amazonino Mendes, even traveled to Chicago to attempt to negotiate sale of carbon benefits on the Chicago Board of Trade—a gesture that is particularly telling given that sovereignty concerns of Brazilian diplomats are the major obstacle to the country's adopting a favorable position on crediting avoided deforestation, and that Amazonino Mendes has long behaved as a vociferous defender of Amazonia against "foreign threats".

Mitigation activities for Amazonia

Here I review six major types of climate-change mitigation activities that have been proposed for Amazonia, examining the pros and cons in economic, social, and political terms, as well as their value as global-warming countermeasures, and their conservation implications. These six options – plantations, agroforestry, soil sequestration, forest management, hydroelectric dams, and avoided deforestation – are summarized in Table 1. It should be emphasized that the area to which a given option might expand (and consequently its potential contribution to mitigating global warming) is limited not only by Brazil's land area but also by the need for maintaining adequate areas in other uses, including food production.

PLANTATIONS

Brazil has one of the world's largest areas of silvicultural plantations—about 5 million hectares in 2000, mainly of *Eucalyptus* species (FAO 2001). The country has been a leading diplomatic force in pushing for plantation expansion as a global-warming mitigation measure, beginning with the FLORAM Project (Ab Sáber et al. 1990) that foresaw an additional 20 million hectares of plantations for carbon in Brazil (mostly outside of Amazonia but also including two areas in the region, the Carajás railway in Pará and Maranhão and the former AMCEL/Champion plantations in Amapá). Although plans under the Clean Development Mechanism are more modest in scale, they could provide a significant impetus for expansion of plantations in Brazil (Meyers et al. 2000, Seroa da Motta and Ferraz 2000). The Bonn agreement of July 2001 allows credit under the CDM for plantations (afforestation and reforestation). Much of the future expansion of Brazil's plantations is likely to occur in Amazonia (Fearnside 1998, 1999a).

A recent initiative to plant 30,000 hectares of *Acacia mangium* pulpwood plantations in Roraima (the Ouro Verde project) includes obtaining carbon credit under the CDM as a long-term goal (STCP 2002). Most advanced on the road to actually gaining credit under the CDM is the 23,000-hectare PLANTAR project in the non-Amazonian state of Minas Gerais (PLANTAR 2003). The PLANTAR project would produce pig iron using charcoal from *Eucalyptus* plantations, although the claimed amount of climate benefit has been questioned (Van Vliet et al. 2003). Smelting pig iron with charcoal has long occurred in the Carajás area (Fearnside 1989a) and proposals for obtaining carbon credit for this activity continue to evolve. By replacing a fossil fuel (mineral coal and coke), charcoal use in smelting accumulates climatic benefits by permanently displacing fossil carbon, in contrast to pulpwood plantations where carbon in biomass and wood products returns to the atmosphere after a temporary period of sequestration (Fearnside 1995a). Displacement of fossil-fuel carbon is considered permanent because the avoided emission cascades forward in time: a ton of fuel not burned this year will be burned next year instead, the ton that would have been burned in year two passes to year three, and so forth. Note, however, that some have argued that fossil-fuel displacement is not permanent because it lowers the cost of future extraction, thereby encouraging future use (Herzog et al. 2003). I have argued that, with over 5 trillion tons of available fossil carbon on Earth, use will ultimately be limited by environmental (climatic) impacts rather than by extraction cost or physical availability (Fearnside 1995a). The Kyoto Protocol considers fossil-fuel displacement to be permanent.

Social impacts are a significant concern in promoting expansion of Brazil's charcoal industry, which is notorious for the degrading conditions in which the workers live, including "debt slavery," where families eternally indebted to patrons are not free to leave the charcoal-making camps (Fearnside 1996a, 1999b, Sutton 1994). Unfortunately, the requirement of "sustainable development" for CDM projects (under Article 12 of the Kyoto Protocol) has been interpreted to be the province of each host country to define (rather than being subject to an internationally standard set of criteria for what constitutes "sustainable development"). Countries can therefore obtain carbon credit for afforestation and reforestation projects that would not meet standards of bodies such as the Forest Stewardship Council, which must conform to international labor conventions whether or not the country in question has ratified those conventions.

Plantations in Brazil are primarily for pulpwood, followed by charcoal production. Longer-cycle plantations for sawnwood are rare. Wood production from plantations therefore does not displace logging in Amazonian forests. Brazil uses wood from Amazonian forests for virtually everything, including concrete forms, pallets, crates, plywood, and particleboard (Smeraldi and Veríssimo 1999). As long as Amazonian wood is available essentially for free, with only the cost of harvest and transportation to pay, one cannot expect to supply these products from plantations. The transition to plantation-wood sources will eventually occur, and it is in the country's advantage to provide mechanisms to achieve that transition while Amazonian forests remain standing, rather than waiting for resource depletion to work through "natural" market forces. Reducing Amazon logging, and the associated reductions in deforestation and surface fires, would have important climate-mitigation benefits.

AGROFORESTRY

Agroforestry, or the combination of planted trees with annual crops, has many environmental and social advantages over predominant land uses in Amazonia, such as cattle pasture (Fearnside 1990, Schroth et al. 2004). Provided that forest is not cut to make way for the agroforestry, trees in agroforestry systems will hold more carbon than would the vegetation otherwise occupying the site (Brown et al. 2000a). Avoided-deforestation benefits are sometimes also claimed, but great caution is needed to avoid exaggeration of these benefits (Fearnside 1999c). Market limits on the products of agroforestry systems, together with other limits, make expansion of these systems unlikely to significantly reduce the vast areas of degraded lands already present in Amazonia (Fearnside 1995b).

An initiative to subsidize agroforestry for its environmental services, particularly carbon benefits, is the PROAMBIENTE project (Mattos et al. 2001). This project would use funds (from Brazil's National Bank for Economic and Social Development) to finance small farmers, beginning with 13 pilot sites distributed among the Amazon region's nine states. Two arrangements are offered, one providing loans followed by payments for environmental services as determined by monitoring, and the other providing only the payments without loans. The creation of banking and organizational arrangements for integrating small farmers into carbon markets has already shown itself to be effective in stimulating agroforestry in Costa Rica and Mexico (Segura and Kindergard 2001, Nelson and de Jong 2003).

Managed secondary forest can provide a variety of products with lower labor and financial investment than agroforestry, provided that land is cheap. Plans for this type of management in degraded pasture lands along the Carajás Railway have been drawn up by the Companhia Vale do Rio Doce mining company. The plan is to use fertilization with powdered charcoal both to sequester carbon in soil and to increase the rate of biomass accumulation. The charcoal fertilization is based on very promising results with annual crops in experiments near Manaus (Glaser et al. 2002), although similar experiments with secondary forest trees have not yet been conducted.

SOIL SEQUESTRATION

Sequestration of carbon in soil through changes in management has considerable potential for climate-change mitigation (Batjes 1998, Batjes and Sombroek 1997, Sombroek et al. 1993). However, the spatial extent of feasible management changes and the per-hectare benefits that these changes can provide are both limited. Because Brazilian Amazonia has an area roughly the size of France in cattle pasture (most of which has very low and declining productivity), the possibility of "recuperating" these vast areas through fertilization has often been raised (e.g., Serrão and Toledo 1990). The finite nature of phosphate deposits in Brazil (and the world) poses limits on this, as do market forces (Fearnside 2002a). In addition, many claims of increased carbon stocks in pasture soil are exaggerated by a failure to account for soil compaction (increased bulk density) under pasture. This compaction makes soil-carbon density appear to be greater than is actually the case, when the pasture soils are compared to natural soils in forests (see Fearnside and Barbosa 1998).

No-till agriculture (direct planting) maintains more soil carbon than does traditional tilling. Because no-till methods are often adopted on the basis of lower cost and greater profitability, independent of carbon benefits, meeting the CDM's requirement for "additionality" (demonstration that the carbon benefits claimed would not have occurred in a baseline no-project scenario) could be difficult. The primary focus of no-till agriculture is soybeans, which are rapidly advancing into Amazonia (Fearnside 2001d).

Soil amendments for agriculture and for recuperation of degraded areas often include application of lime. Use of lime, either as limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$), releases CO_2 when added to acid soil. These emissions must be considered in assessing the net benefit of the recuperation program. The same is true for carbon stocks in biomass, including underground biomass. Carbon losses from removal of woody plants, for example in recuperating degraded pastures, must be counted in assessing net benefits.

Carbon can be stored in soil in the form of charcoal (which decomposes very slowly), rather than increased organic carbon, which is the focus of most soil-carbon sequestration initiatives. Recent experiments showing dramatic yield increases when powdered charcoal is included as a soil amendment (along with modest amounts of fertilizer) have led to considering this as a part of soil-improvement proposals under the Terra Preta Nova project (Glaser et al. 2002, Sombroek et al. 2002). This initiative hopes to recreate the anthropogenic black earths (*terra preta do índio*) that modern inhabitants of Amazonia have inherited from pre-Colombian indigenous populations. The patches of black earth that dot the region today contain much more organic matter than do other soils, in addition to containing black carbon (charcoal). Artificial establishment of black earths offers the hope of more productive and sustainable agriculture and agroforestry, in addition to its climate-mitigation potential (Sombroek et al. 2003).

FOREST MANAGEMENT

Sustainable forest management has often been suggested as a form of carbon sequestration because carbon in wood that is converted to long-lived wood products, such as fine hardwood furniture and construction timber, remains out of the atmosphere while the trees in the harvested location re-grow and accumulate more carbon (e.g. Myers 1989). However, the fraction of the carbon stock that actually ends up in long-term products is miniscule, and short-term releases of much larger amounts of carbon take place from decay of the slash, stumps, and roots and from the many unharvested trees that are damaged or killed during the logging process. These losses more than outweigh the wood-product pools for many decades, and any value attached to time completely negates the very slow rise of carbon stocks in long-term products that can result from forest management (Fearnside 1995a). (Valuing time, most commonly done by applying a discount rate, converts the value of future costs and benefits to their present-day equivalents for the purpose of comparisons in decision making; invariably, future events have less weight than current ones, but the appropriate weighting is a matter of controversy; Fearnside 2002b).

An additional key concern is that logging, even as a part of sustainable forest management, greatly increases the flammability of the forest and the risk of ground fires (Uhl and Buschbacher 1985, Uhl and Kauffman 1990, Cochrane et al. 1999, Nepstad et al. 1999a, 1999b, Cochrane 2003, Laurance, chap. 5). These fires result in tremendous emissions and set in motion a recurring cycle of tree mortality and re-burning that can degrade the entire forest (Barbosa and Fearnside 1999, Cochrane and Schultz 1999, Nepstad et al. 2001, Gerwing 2002, Barlow et al. 2003, Haugaasen et al. 2003, Barlow and Peres, chap. 12). Forest management plans, including those anticipating carbon benefits, virtually never consider the implications of increased ground-fire risk (Eve et al. 2000).

Reduced Impact Logging can have more immediate carbon benefits. Traditional logging practices in Amazonia, which can even involve wandering through the forest on bulldozers in search of logs, causes much more damage (and carbon emission) than does the loss of the harvested trees themselves (Johns et al. 1996, Uhl and Vieira 1990, Uhl et al. 1991, Veríssimo et al. 1992). Institution of known low-impact techniques therefore has immediate benefits for carbon, as well as for forest sustainability (Putz and Pinard 1993, Pinard and Putz 1996, 1997, Boscolo et al. 1997, Healey et al. 2000).

Avoided logging is another option with significant carbon benefits. The only example to date is in Bolivia, the Noel Kempff Mercado Climate Action Project (Asquith et al. 2002, Brown et al. 2000b). The project was negotiated by The Nature Conservancy, is financed by a consortium that includes American Electric Power and British Petroleum, and is owned and run by the Bolivian NGO Fundación Amigos de la Naturaleza (see Ellison and Daily 2003). The logging company that formerly exploited the area signed a "leakage agreement" to prevent re-investment of the funds in logging elsewhere. A system of monitoring tracks carbon stocks, as well as other features of the program such as the services and other benefits provided to surrounding communities.

HYDROELECTRIC DAMS

Hydroelectric dams are often promoted as climate-friendly energy sources, and credit for hydroelectric projects is permitted under the Kyoto Protocol for projects with a power density of more than 10 Watts of installed capacity per square meter of reservoir area. Depending on how power density is calculated, the Belo Monte Dam, planned on Brazil's Xingu River, could qualify, and the dam has often been mentioned in this context by Brazilian authorities. However, Belo Monte only reaches the very high power density of 10 W m^{-2} if the calculation is made by ignoring the much larger areas of reservoir that would have to be created by additional dams upstream in order to regulate the flow of the Xingu River and make use of the full 11,000 Megawatts of installed capacity planned for the dam (Fearnside 1996b, 2001e).

An additional problem with using hydroelectric dams as a form of climate mitigation is that the dams themselves produce substantial emissions. Part of this comes during the first years of dam operation from the decay of trees that project above the water surface when the areas are flooded (Fearnside 1995c). Another large emission comes from methane produced by decay in the reservoir itself; much more important than the flooded wood biomass is the soft, rapidly decomposed organic matter in macrophytes (especially in the early years of a reservoir) and in the weeds that repeatedly grow and are flooded in the drawdown areas as the water level fluctuates. Only modest impacts are indicated if only the emissions from bubbling and diffusion through the reservoir surface are counted, as in the estimates currently being used for Brazil's national inventory of greenhouse gas emissions (Rosa et al. 2002). Unfortunately, if the much larger emissions from the water that passes though the turbines and spillway are considered, the emissions are approximately ten times greater in the case of the Tucuruí Dam (Fearnside 2002c). Furthermore, hydroelectric dams have additional emissions from the concrete, steel, and other components of the dam construction itself, and these emissions occur years before any power is generated. Because emissions are greatest and generation is least in the early years of a dam, in contrast to electrical generation from fossil fuels, any value given to time in global warming calculations weighs heavily against hydroelectric power (Fearnside 1997a).

Perhaps the greatest problem with hydroelectric dams as climate-mitigation measures is the tremendous environmental and social impact of these developments (Fearnside 1999d, WCD 2000). Although the CDM is supposed to be restricted to sustainable development, the decision to allow each country to define sustainable development for itself leaves the way open for projects with major impacts to gain credit. There could be no better example than Belo Monte: the upstream dams needed to regulate streamflow for Belo Monte would flood vast areas of tropical forest, almost all of it indigenous land, including over 6,000 km^2 for the Altamira Dam (formerly Babaquara Dam; Santos and de Andrade 1990, Fearnside 1999d).

AVOIDED DEFORESTATION

Avoided deforestation is the subject of debate on several different levels. One series of debates concerns the underlying data, such as the biomass of the forest and of the replacement vegetation. On another level are debates over the theoretical issues that determine how much climatic value avoiding a hectare of deforestation would have, while a third level involves the political interpretation of these results.

Forest biomass is a key measure, as carbon emissions are directly proportional to biomass, with only slight variations due to biomass effects on burning completeness and consequent trace-gas emissions. A wide range of estimates has been produced for the average biomass of Amazonian forest (see reviews in Fearnside 1997b, 2000b, Fearnside et al. 1993). If a low value from this range is picked, the result is a low estimate of deforestation emissions (and therefore of the benefits of reducing deforestation). Examples are provided by a series of Brazilian government estimates indicating little or even zero (!) emissions from Amazonian deforestation (see review in Fearnside 2000c). The choice of input parameters is often treated in a manner equivalent to picking a breakfast cereal in the supermarket, where one can pick whatever cereal one happens to like. Unfortunately, going into the literature to find a value for forest biomass is not the same as picking a breakfast cereal: some values are much better than others in terms of the underlying data and in the interpretation of those data. A recent debate over the biomass of Amazonian forests, and how to interpret it in terms of net emissions of greenhouse gases, illustrates this point (Achard et al. 2002, Eva et al. 2003, Fearnside and Laurance 2003, 2004). Great care must be taken that all components of the carbon stock are included, such as dead biomass, small-diameter trees, vines, palms, strangler figs, and other “non-tree” components, and belowground biomass. The full emission must include either the “committed emissions” after the year or (or multi-year time period) used for the estimate, or the “inherited emissions” from decay or combustion of biomass that remains unoxidized from deforestation in the years prior to the year or period of interest. Regrowth in deforested landscapes of Amazonia are often overestimated by using data on secondary forests that are not derived from cattle pasture (which overwhelmingly predominates as a land-use history and which produces secondary vegetation that grows only slowly; Fearnside 1996c, Fearnside and Guimarães 1996). To fully reflect the global-warming impact of deforestation, emissions of trace gases such as CH_4 and N_2O must be included, not only from carbon (i.e. CO_2). Inclusion of trace gases increases the impact of deforestation by 15.5±9.5% over calculations that only consider carbon (Fearnside 2000b, pp. 143-145). All of the above factors are omitted in varying degrees from a number of widely used emissions estimates for Amazonian deforestation (see Fearnside and Laurance 2003, 2004).

The value of time is fundamental to the place of avoided deforestation in global-warming mitigation. Decisions on discounting or other forms of time-preference weighting (Fearnside 2002b) and on the time horizon for carbon accounting (Fearnside 2002d) make a tremendous difference in the credit assigned to avoiding deforestation, as compared to options at the two ends of the spectrum of permanence (the time that carbon remains out of the atmosphere): permanent displacement of fossil-fuel carbon and short-term sequestering of carbon in biomass in plantations. Heavy discounting of future costs and benefits favors plantations, while insisting on only “permanent” carbon (i.e. zero discount) favors fossil-fuel options (see numerical examples in Fearnside 1995a). The discussion of this is highly polarized, with groups opposed to all “sinks” (e.g. European NGOs) insisting that only “permanent” carbon be credited at all (e.g., Hare and Meinhausen 2000, Meinhausen and Hare 2000, WWF Climate Change Campaign 2000). However, the underlying philosophical position that a ton of carbon emission hundreds or even thousands of years in the future should be given the same weight in decision-making as a ton of carbon emission today (i.e. zero discount) is completely at odds with the way human decisions are actually made (see Fearnside 1995a, 2002b). Because global warming is essentially a permanent shift in climate and associated probabilities of disasters, there is value to delaying global warming that is independent of questions concerning the pure time preference. A delay in global warming from time “one” to time “two” saves the lives that would have been lost to global-warming impacts between times “one” and “two.” The question of what value should be assigned to time is a moral and political one, rather than a scientific one, and should be decided democratically after ample debate.

Various carbon-accounting frameworks have been proposed that establish an equivalence between carbon held out of the atmosphere for different lengths of time, including “permanent” displacement. “Ton-year” accounting methods represent one approach (Fearnside et al. 2000, Moura-Costa and Wilson 2000), but a method that is more likely to gain acceptance in international negotiations is Temporary Certified Emissions Reductions (T-CERs), based on what is known as the “Colombian Proposal” (Blanco and Forner 2000, Kerr and Leining 2000). This arrangement would allow market forces to determine the relative prices of certificates that correspond to carbon held out of the atmosphere for different lengths of time. When the certificates expire, they would have to be replaced either with a permanent fossil-fuel carbon displacement or with another temporary certificate, thereby solving the problem of "permanence" from the perspective of the climate. Means of limiting ("capping") the cost of these measures have also been proposed that alleviate a variety of diplomatic concerns (Schlamadinger et al. 2001). It is noteworthy that the European NGOs opposed the Colombian Proposal when it was first forwarded in October 2000, but abruptly reversed positions after the Bonn Agreement of July 2001. In 2002 twelve countries submitted views on the modalities governing these issues under the Kyoto Protocol, including refinements by Colombia and the European Union. Additional proposals from the academic community for transforming T-CERs into a system of "renting" carbon offsets (Marland et al. 2001), or to combine T-CERs with calculations based on the ton-year approach (Dutschke 2002), provide solutions to other perceived problems. The upshot is that if countries want to find solutions to the permanence "problem" they are quite capable of doing so, but if they want to seize on permanence as a excuse for excluding forests, they are also capable of pretending that the issue is insoluable.

"Leakage," or spillover effects outside of a project's boundaries that can negate the climate benefits achieved by the project, is one of the characteristics of project-based mitigation, including many energy-sector projects as well as forest-sector ones (Brown et al. 2000a, Fearnside 1999c). This can happen, for example, if farmers prevented from deforesting in a project area simply move elsewhere in the region and clear the same amount of forest at their new location. A variety of ways exists to design projects that minimize leakage effects, as well as for monitoring and compensating for the leakage that occurs (e.g., Brown et al. 2000a). A key assurance against leakage is carbon crediting that only pays for carbon benefits that have been achieved and verified, as opposed to mere plans or promises. The important thing is that leakage is a problem that can be minimized and adjusted for, and is not a justification for abandoning the effort to develop avoided deforestation as a mitigation strategy.

The same can be said for the difficulties in establishing an appropriate baseline or reference scenario for use in quantifying the "additionality" of the project effects (required for CDM projects under Article 12 of the Kyoto Protocol). "Additionality" refers to the need to demonstrate that the carbon benefits claimed would not have occurred in a baseline no-project scenario. Because the no-project scenario against which project results are compared is, of necessity, a hypothetical one, it carries uncertainty and a possibility of being "gamed" to falsely claim carbon credits. Again, various proposals exist to standardize procedures and minimize risks. The important thing is that uncertainty can be incorporated into the calculations and adjusted for in the credit granted. The fact that some mitigation options (such as avoided deforestation) have more uncertainty than others (such as plantations for charcoal) does not render the more-uncertain ones valueless. In fact, the large "jackpot" of climatic benefits from a successful program to slow deforestation is such that its expected value (the sum of the products of each possible result and its respective probability of being achieved) can be much higher than lower-risk options (Fearnside 2000d).

By insisting on very high levels of certainty, one effectively throws out the chance to make much more substantial advances in the fight against global warming. Uncertainty requirements represent a situation analogous to the problem of Type II error in statistics: by focusing all attention on reducing Type I error (the probability of mistakenly accepting a statement as true when it is not), one increases Type II error (the probability of not identifying a phenomenon that really exists), and can completely defeat the larger purpose of a study. In this case, it is the larger purpose of maximizing our reduction of global warming that is defeated by insistence on unrealistic levels of certainty for avoided deforestation measures (see Fearnside 2000d). Because the amount of carbon in each hectare of forest saved is so large, the effect of uncertainty can be more than compensated for by giving less carbon credit (Certified Emissions Reductions) than the amount of carbon actually present in the trees. Critics of avoided deforestation (e.g. WWF Climatic Action Campaign 2000) virtually always make the unstated assumption that there is a one-to-one ratio between the amount of carbon credit given and the amount of carbon in the project's trees, such that any loss of biomass carbon represents a loss to the atmosphere. However, there is nothing in the Kyoto Protocol that specifies such a one-to-one ratio, and one can easily make deals that are advantageous to the atmosphere even in the face of impermanence, leakage, and uncertainty. Especially in the case of avoided deforestation, one can get substantially more real carbon than the face value of the credits that are given in exchange (Fearnside 2001a).

Climate change itself has become an excuse for rejecting avoided deforestation as a mitigation measure. The U.K. Meteorological Office Hadley Center's HadCM3 model (Cox et al. 2000) indicates climate change decimating Amazonian forests by 2080, while the dieback shown by a subsequent version of the model (HadCM3LC) is slightly less but still catastrophic (Cox et al. 2003). Early results of these models were seized upon by opponents of avoided deforestation as a justification for their positions (e.g. WWF Climate Change Campaign 2000). Needless to say, one might question whether such a finding, even if it were known with high certainty, would make it appropriate for environmental organizations to refuse to take up one of the most important potential weapons in the fight to save tropical rainforests. With over 80% of Brazil's Amazon forest still standing, it is difficult to imagine throwing in the towel on the assumption that the forest is doomed anyway. But even if the forest is doomed, the proper place of environmental groups is to be fighting to save it tree by tree, rather than giving up in advance. If the forest only lasts for 80 years, then avoiding deforestation should be given a maximum of 80 years of credit rather than zero.

So, where do we stand in efforts to turn avoided deforestation into a mitigation measure on a scale that has significant benefits both for climate and for other conservation objectives? Much remains to be done. One area is the impact of planned infrastructure projects in Amazonia, which imply large increases in deforestation and greenhouse gas emissions (Laurance et al. 2001, Nepstad et al. 2001, Fearnside 2002e). Were the decision-making process to take full account of the environmental costs of these projects, including their global-warming impacts, many would be seen as counterproductive and would not be undertaken. Progress has been minimal in incorporating such concerns into the planning process, despite frequent statements of intentions. Were credit for avoided deforestation a reality under the CDM, the motivation for such changes would increase dramatically.

Several kinds of strategies exist for reducing deforestation. One is to enforce the existing legislation (i.e. Brazil's "Forest Code") to reduce illegal clearing in private properties, particularly large properties. Because deforestation is largely for low-productivity cattle ranches belonging to wealthy landholders, the rate of forest loss could be substantially reduced without inflicting social costs (Fearnside 1993). An encouraging example is provided by a deforestation licensing and control program in the state of Mato Grosso, which showed strong indications of having a significant effect on clearing rates in the state over the 1999-2001 period (Fearnside 2003a). Unfortunately, deforestation surged upward in Mato Grosso, and throughout Amazonia, in 2002. (In Mato Grosso this may, in part, have reflected anticipation by large landholders of the October 2002 elections, when Blairo Maggi, the largest soybean entrepreneur in Brazil, was elected as state governor.) Notably, the estimate for 2001 deforestation in Mato Grosso produced by Brazil's National Space Agency (INPE 2003) was inconsistent, both in magnitude and direction, with data from the Mato Grosso state government for clearing of rainforest and transitional forest (Fearnside and Barbosa 2004). Assuming that the decrease indicated by the state-government data is real, then the program's results are very important in demonstrating that deforestation is not beyond the control of government policies—a belief that lies at the core of the Brazilian Foreign Ministry's traditional opposition to recognition of carbon credit for avoided deforestation (Fearnside 2003a). It also implies substantial climate benefits over the 1999-2001 period (Fearnside and Barbosa 2003).

Enforcing legislation affecting private landholders is only one strategy for reducing and containing deforestation. Another is the creation and protection of various types of reserves. Most important of these are indigenous reserves, which have much larger areas and potential environmental significance than do the smaller areas designated as conservation units (Fearnside and Ferraz 1995, Fearnside 2003b). Negotiation with indigenous peoples has yet to begin and is an urgent priority. The satellite data from Mato Grosso show that, although most indigenous groups live up to their reputation as much better forest guardians than their non-indigenous counterparts, a few groups are allowing substantial clearings in their reserves (Fearnside 2002f). This points to the urgency of making the as-yet unremunerated environmental services of the forest a real source of income for indigenous groups. The best environmental results can be expected from direct payments for the services provided, rather than from indirect subsidies of activities like ecotourism or sustainable forestry (Ferraro and Kiss 2002). Indigenous peoples, as well as non-indigenous groups in Amazonian forests, must understand that their greatest asset is the environmental service of forest maintenance.

The Clean Development Mechanism of the Kyoto Protocol is only one way that Brazil could gain carbon credit for avoided deforestation. Were Brazil to join Annex I of the United Nations Convention on Climate Change (UN-FCCC) and Annex B of the Kyoto Protocol, credit could be gained through emissions trading (Kyoto Protocol Article 17), without such limiting restrictions as showing additionality and having detailed, georeferenced accounting for carbon stocks. Emissions trading under Article 17 is based on the much simpler National Inventories that are required of all signatories to the 1992 UN-FCCC. Because Brazil had a net emission of carbon from forests in 1990, Article 3.7 of the Protocol (the "Australia clause") guarantees that these emissions would be part of the country's assigned amount, and that any reduction below the 1990 level of emissions could be sold as carbon credit (Fearnside 1999e, 2001c). This could happen whenever the country decides to do so, even in the 2008-2012 commitment period, but would require that Brazil accept a cap on its national emissions of greenhouse gases. However, because the great majority of Brazil's emissions come from deforestation that produces little benefit to the country's economy and people, Brazil could limit or reduce its emissions more easily than virtually any other country in the world.

Whether Brazil takes advantage of its potential for climate mitigation through avoided deforestation is entirely up to the Brazilian government, or, more accurately, to the individuals who make up the responsible ministries within the government (Foreign Affairs and Science and Technology). Because opinions are so diverse on the issue, it is essentially a toss of a coin each time a new set of ministers is appointed. I believe that, sooner or later, individuals who support avoided deforestation will occupy these posts, and that once the country's negotiating position changes there will be no going back.

One must take a long-term view of the question of avoided deforestation. When I first began advocating forest maintenance for environmental services in 1985, the concept was essentially unknown (see Fearnside 1989b). Quantification of potential benefits prior to the Kyoto Protocol (e.g. Fearnside 1995a, 1997c) seemed highly theoretical at the time. Since then there have been enormous advances, both in the science and in the diplomacy related to this question. The five-year setback represented by the Bonn Agreement, although unfortunate given the pace of destruction in Amazonia, is minor on the longer scale of conservation efforts in the region. Further reducing the uncertainties associated with the benefits of avoided deforestation and the means of achieving them must remain a major priority for science. Pushing for acceptance of avoided deforestation both by the parties to the Kyoto Protocol and by the Brazilian foreign ministry must remain a major priority of conservation groups that defend Amazonian forests. Avoided deforestation cannot continue unrecognized for long: the arguments in favor of avoiding tropical deforestation as a major part of global efforts to mitigate climate change are too strong, and the benefits of tapping this source of value are too great to ignore.

CONCLUSIONS AND IMPLICATIONS

1. Forest loss and degradation in Amazonia currently make a significant contribution to global greenhouse gas emissions, and the large areas of surviving Amazonian forest mean that the potential for future emissions is greater than in other tropical areas where deforestation is more advanced. Policy changes that slow deforestation in Amazonia therefore have large potential climatic benefits. In addition to global warming, Amazonian deforestation also contributes to climate change through large effects on water cycling, heat transport, and aerosols. In the case of Brazilian Amazonia, where deforestation is largely for low-productivity cattle ranches belonging to wealthy landholders, the rate of forest loss could be substantially reduced without inflicting significant social costs.

2. Mitigation plans in Brazilian Amazonia have so far been concentrated on silvicultural plantations, such as *Eucalyptus* trees for charcoal production. The social and biodiversity benefits of these efforts are limited. Agroforestry (for example under the PROAMBIENTE project) is also planned, with greater potential for such benefits. Hydroelectric dams are often mentioned in this context of mitigation, but the social and environmental impacts (of which greenhouse-gas emissions are only one) make this a questionable option.

3. The agreement reached in 2001 regarding the Kyoto Protocol's first commitment period (2008-2012) rules out credit under the Clean Development Mechanism for avoided deforestation. However, inclusion of this option is likely from 2013 onwards. Of all the mitigation measures, avoided deforestation could have the greatest potential benefits in Amazonia, in concert with other options such as avoided logging, reduced-impact logging, and forest-fire avoidance. An environmental licensing program in the state of Mato Grosso over the 1999-2001 period offers valuable and encouraging lessons on how deforestation could be reduced on a wider scale in Amazonia if the environmental services of the forest, such as in mitigating climate change, are properly rewarded.

4. Potential climate-mitigation measures in Brazilian Amazonia, especially avoided deforestation, could also be applied in other Amazonian countries and in tropical forests generally. Quantifying the costs and benefits of these measures and strengthening the institutional structures that assure their effectiveness should be major priorities in counterbalancing the growing list of emerging threats to tropical forests.

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Table 1. Comparison of mitigation options in Brazilian Amazonia.

Mitigation option	**Magnitude of potential climate benefit**	**Magnitude of financial costs per ton of carbon**	**Types of social and political costs and benefits**
Silvicultural plantations			
For pulp	Modest due to short-term nature of sequestration	Relatively high cost per ton of C equivalent to permanent sequestration	Employment
For sawnwood	High on long term from logging displacement	High at present due to competition from low-cost timber from Amazonian forests	Employment
For charcoal	High, due to permanent nature of C displacement and Brazil's very large high-grade iron deposits.	Low	Potential for strong negative impacts due to traditions of debt slavery and child labor in charcoal making
Agroforestry	Modest due to market limits	Moderate	Social benefits for small farmers
Soil sequestration			
Terra preta (black earth)	Substantial	Unknown	Social benefits if for small farmers
No-till agriculture	Low due to little additionality	Very uncertain: cost is low per hectare because no-till is often profitable in its own right; for same reason little carbon is additional.	Mostly for large soy farmers

Pasture management	Low: despite large areas of pasture, results are slow and phosphates limit extent to smaller areas	High, especially if time value given to carbon	Mostly for large ranchers
Charcoal amendments	High due to large areas of degraded pasture in which amendments might be applied for various land uses. Note: P limits extent of pasture recuperation.	Unknown	Low social benefits if for secondary forest (e.g., Carajás proposal)
Forest management			
Wood product sequestration	Very low or negative	Infinite cost if benefits zero or negative	Neutral
Reduced-impact logging	Substantial	Low (if all C is considered additional)	Modest benefits. Little to small landholders
Avoided logging	High. Approximately 60 million t C current annual emission.	Low	High loss on site. If substitution from plantations, then supply generated elsewhere.
Hydroelectric dams	Much smaller than officially recognized in Brazil	Relatively high.	Very high impacts
Avoided deforestation	Very large. Approximately 450 million t C current annual emission.	Low financial cost (costs are political)	Beneficial; political cost in slowing deforestation

Figure Legend

Fig. 1. Brazilian Amazonia and surrounding areas, with locations mentioned in the text.

Fig. 1


Ouro Verde Plantations
AMCEL/Champion Plantation
Roraima
Amapá
Belém
Amazon River
Manaus
Altamira Dam
Belo Monte Dam
Tucuruí Dam
Carajás Railway
Amazonas
Pará
Río Xingu
Acre
Tocantins
Rondônia
Mato Grosso
Noel Kempff Mercado Reserve
Brasília
Plantar Plantation
Minas Gerais
São
Paulo